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THE NEW VISION

# WORLD BENEATH THE MICROSCOPE

THE NEW VISION

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   by W. Watson-Baker

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# WORLD BENEATH THE MICROSCOPE

## by W. Watson-Baker

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**First Published 1935**

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THE world beneath the microscope is one of the several aspects of science which have long been accepted as a marvel and come to be taken as a matter of course. The phrase even retains a faintly Victorian savour, suggesting amateur science in the days before the automobile, the airplane, and the wireless when Microscopical Societies abounded and earnest young people were anxious to follow Thomas Henry Huxley's advice and " get a little sound, thorough, practical elementary instruction " in biology and so on.

An examination of the " lowly stock whence man has sprung " was comfortably pursued by the fireside in the more enlightened middle-class homes, secure upon the summit at the end of the evolutionary climb.

It is possible that the organized common sense which was the scientific watchword of the period was somewhat damping to the imaginative faculty; but it is certain that the microscope became in the course of time a property of the specialist alone, a means to certain expert ends. The disciple of Dr. Thorndyke is entranced to find that that master of detection, by scrutinizing a hair through the lens, can at once trace a crime to an elderly Japanese, wearing a bowler hat habitually and living in a particular street in the East End of London. Neither Dr. Thorndyke nor the reader was previously aware of the existence of the Oriental offender. The hair and certain minute substances, when vastly enlarged, somehow revealed the information, in a manner which, speaking without the book, I have now forgotten. Evidently, however, the keen eye of Thorndyke did not so much *see* what was under the microscope as the implications of what was there. He did not murmur to himself, " I have found a new world of surpassing beauty;" he murmured: " I have found an elderly Japanese."

We know that the microscope helps to solve such mysteries, though as laymen we are more interested in the end than in the means. In the same way we know that the microscope saves lives from disease, that it discloses to the pathologist diagnoses which otherwise would be a matter of guesswork. For this we are grateful to the pathologist and we expect nothing more from him: though had Dante been a pathologist and applied his eye to the microscope before writing of the " Inferno " we might have had such a description of a truly diabolical host as would have aroused the deepest emotions.

There is no need to describe here at great length the practical functions which the microscope can perform. It examines and tests a new product for the manufacturer, reveals the hidden fungus spores which have ruined rolls of fabric, or the sinister activities of an insect which has ravaged a countryside.

It remains only to *see* this new world *as* a new world, in which enterprise we are helped by that sterling ally of the modern vision—the camera. The photograph shows us the actual shape of things under the microscope, and photomicrography—the regrettable word combination which we use only because it is the accepted form—is the true subject of this book.

For those who are not detectives, or pathologists, or botanists, who have never even heard of the " Bell" animalcule or the " Diatomaceæ," the photomicrograph may revive interest in this crowded, gaudily-patterned universe that lies so close to but just outside our vision. There are rocks of crystal more forlorn and desolate than the strange landscape background of the Monna Lisa ; twirling hordes of monsters voracious and ferocious ; spreading tree-like structures that in actuality are a grain of invisible dust ; exquisite plumes, delicate columns ; robot creatures with quasi-mechanical joints ; organisms, like engines, just beginning to live : fanciful streamers and bubbles of beauty. In all this there is something abstract, something of the essential nature of visual things.

This exists around us and our fallible senses, our dull protective envelope have told us nothing of it. It seems a suitable moment indeed for the rediscovery of the microscope, this moment when thought juggles so much with the large and the small. Life to-day, it is a commonplace to repeat, becomes quicker in tempo and therefore more summary in expression. Journalism is swift, lucid, terse. At the same time an explanation of the minute seems to have become a necessary complement to hustle. In the vast leisurely epic of Marcel Proust, no thought or feeling is too apparently wayward or meaningless to be recorded. The protoplasm of the intellect with its multiform hidden combinations is exposed to view on a mental slide. This is a characteristic adventure in fact of modern times—a part of the search for more profound knowledge and greater understanding—leading into strange paths and away from the normal human scale to find a meaning in the obscure and a pattern in the invisible—a riot of sound in the silent air.

We are no longer so excited as formerly by the account of trips on the surface, by jolly coaching journeys, meeting new people and seeing new places and customs, for we have done, or at all events think we have done, all this before. The mind is stretched, uncomfortably sometimes, but with a new fascination, to speed and profundity, to the thought of worlds that lie a million light-years away from us, to the worlds that recede in evolutionary time beneath the lens, to the thought even that they merge or that by some extraordinary trick of relativity the smaller may contain the large. There is an affinity between the telescope and the microscope, between the discovery of stellar space and the discovery of the atom.

The artist feels what the scientist calculates. As serious writers have abandoned the superficial devices of the picaresque novel and begun to explore the mind, as the composer leaves established harmonies and seeks for deeper runlets of emotional sound, the visual artist is urged to exchange the delineation of outward appearance for a nearer examination of form. The symmetrical exemplars of text-books on design prove to be of the utmost banality when compared with the enormous repertoire of design in nature, a dimensional book which discloses repertoire within repertoire, cosmos within cosmos. We turn over the page which illustrates obvious symmetries and regularities ; we scent more vital stuff in a new series overleaf of designs that man has only faintly conceived, in whose prodigal scrawls the restless motion of primary life sketches an unprecedented art.

The artist will not painfully copy this new world, but he will be the more an artist for seeing it. Let us ask the photographer, however, to explore for us and to bring back fresh evidence of infinity on his plates and film, enabling us as people of the modern world to take cognizance of a fairy-tale exceeding in fantasy the lore of giants and dwarfs and the adventure of Gulliver in the rôle of Quinbus Flestrin, the man mountain, holding Lilliput in the palm of his hand.

W. GAUNT

## WORLD BENEATH THE MICROSCOPE

To the uninitiated everything associated with the microscope seems beyond the range of ordinary interest—a matter of study rather than an escape from the pressing anxieties of daily life. Yet until forty years ago a microscope was considered a necessary possession by every educated family. From the 1850's until the 1890's a continuous stream of popular literature dealing with the subject issued from the press, in itself an indication of the very live interest evinced by the public.

In later years the motor-car, and more recently wireless, have diverted interest from the microscope, but there are increasing signs that thinking people are turning to microscopy again; the membership of natural history and microscopical societies shows steady increase, and a large proportion of the recruits are not those to whom the more energetic amusements are barred, but younger people.

Astronomy as a hobby has shown an increasing, albeit limited appeal. In these islands it can with advantage be pursued during the winter months. There is a fascination in the contemplation of infinite space, the movements of the planets, the speculation upon their composition and purpose, but the opportunities are relatively few for pursuing this hobby, and the avenues of work restricted, while instruments for more advanced work are costly.

Microscopy is not an expensive pastime, while its variety is as infinite as Nature herself. The garden, a pond, the seashore, rivers, all have their own secrets, many of which still await solution.

Consider the design of the Radiolariæ, Diatomaceæ, the sea urchin's spines and the fern stems, shown in the following pages. For mechanical strength to resist deep-water pressures, elasticity to give to wind force and yet remain unharmed, protection and withal the combination of strength and utility with delicate appearance and beauty, has anything more successful been evolved by even the most advanced designers of the present day with the wealth of experience upon which they are able to draw? All their achievements and more have been anticipated by Nature. Some of the fossil forms date back to antediluvian times. So the structural engineer, the architect and the designer can all learn from the microscope and take it into partnership in their work.

There is a method employed in the examination of chemical crystals, geological materials, fibres, metals, etc., known as polarised light, by means of which light passing through different materials is split into its component colours; by the variations and intensity of these colours and their changes differences can be distinguished. Apart from the intrinsic scientific value of this technique the infinite combinations and gradations of colour that it offers are in themselves delightful.

In industry the aid of the microscope is invoked in every step from the raw material to the finished article. The steel worker can determine the homogeneity of his melt, the fracture under strain of a piece of metal can be immediately analysed. Adulterations in food, disease in animal carcases can be detected by its aid; in brewing, confectionery, dairying and so forth, it is all-important.

Turning to the human aspect, consider its assistance in public health and the control and cure of disease. The work of Pasteur on anthrax would have been impossible but for the microscope, while Koch in his discovery of the cholera bacillus, Ross on malaria and sleeping sickness, would have been helpless without it. It is used in ante-natal work upon puerperal fever in controlling and diagnosing disease, in forensic investigations, and in determining cause of death. From before birth until after decease every problem affecting humanity comes before the microscope for final decision.

A short description of the apparatus itself may be of interest to the reader. Any magnifying glass may be termed a " simple " microscope in that it magnifies the object seen by the naked eye. A " compound " microscope, which is more commonly employed, consists essentially of two main elements, the Objective and the Eyepiece. Of these the more important is the objective. This forms an image of the specimen and magnifies it, the image being an aerial one which in turn is picked up and magnified by the eyepiece: the primary and greater magnification is imparted by the objective.

Mere magnification is insufficient. Two other factors come into account: " achromatism " or the combination at focus of the component colours of light so that no colour fringes appear upon colourless objects, and " resolving power " or the ability to separate a given quantity of lines per inch. Thus some of the highest power modern objectives, with correct illumination and eyepieces designed to work in combination, are able clearly to divide approximately 140,000 lines per inch—for the elucidation of some structures the whole of this ability is necessary.

As magnification and resolving power increases, so the size of the front lens and the area examined decreases and some means of illuminating the specimen by concentrating the light becomes essential; the lens system adopted for this is known as the condenser. (It should be remembered that in the microscope such accessories as the eyepiece, objective and condenser are all in reality lens systems and consist of several lenses.) The illuminant employed depends upon the specimen to be examined; the microscopist employs all forms of light sources from the oil lamp to the mercury vapour arc.

The optical parts themselves must be mounted upon an instrument (the microscope stand) which is provided with such movements as will enable the user to develop the potentialities of the optical parts available. The essentials of such a stand are: complete freedom from vibration or flexure; coarse or rough adjustment by rack and pinion; fine adjustment which should move the objective a maximum of 1/125th for a complete rotation of the fine-adjustment milled head; bearings which are smooth and accurately parallel with the optical axis of the instrument; a stage of metal covered with vulcanite or similar material, or of metal only; a carrier for the condenser, preferably with some form of focussing adjustment; mirrors, plane and concave; a foot which imparts basic rigidity to the instrument at all angles of inclination.

The last plate in this book shows a microscope fully equipped for research work, incorporating features not included in the brief survey above, which is only intended to indicate the minimum equipment for a beginner. On this the objective lenses are mounted upon a nosepiece so that they can be interchanged with a minimum of delay, a binocular body is provided and a special prism device incorporated so that the eyepieces are inclined to a convenient angle while the stage remains horizontal for the examination of objects in fluid. The stage, or object carrier, is provided with mechanical movements so that the whole area of a specimen can be systematically examined, with rotation and centring screws for orientating a specimen when being photographed, or for use with polarised light. The substage or condenser carrier is fitted with rack and pinion focussing, screws for accurately aligning the condenser in the optical axis of the objective and eyepiece, and a method of rapid interchange for various types of condenser.

For details of microscope technique the reader is referred to the excellent text-books available. " Modern Microscopy " by Cross and Cole, " The Microscope " by Wright and Drew, and " The Beginner's Guide to the Microscope " by Hall, may be specially mentioned.

To the beginner the main essential in the selection of a microscope, apart from the features mentioned, is that it should be standardised throughout so that additional fittings and movements can be fitted by the owner himself and in such a manner that these extras on attachment become integral parts and homogeneous with the instrument itself, not mere unsightly additions, cramped, lacking in rigidity and limited in their utility.

It should be the aim of the beginner to commence with low power objectives, and to endeavour to wrest the uttermost from these before proceeding to the higher powers of the microscope, remembering that resolution and not mere empty magnification is his goal in technique.

A few remarks may help in the interpretation of the illustrations themselves. Certain structure is visible upon the exterior of any specimen; often this may be adequately examined by means of a simple microscope or hand magnifier having a magnification of 10 diameters. Such a lens should be achromatic, and about ½ inch diameter. With this considerable information may be gleaned regarding the pores of plants, formation of flowers, grasses, crystalline structures, hairs, fibres, etc. Such information is essential to the correct interpretation and intelligent understanding of a considerable proportion of the internal structure.

For the examination of the stems of trees, the tissues composing organs, crystals and structures in geological formations, etc., which are opaque to light and of considerable thickness, other methods of attack are needed. The object for examination is either embedded in pith or carrot, frozen, or infiltrated with celloidin or paraffin wax. It is then mounted upon a cutting machine known as a microtome, by means of which, according to its pattern, slices or sections as thin as 1/25000th of an inch can be consecutively cut. This method is employed for the systematic reconstruction of organs and glands, the whole being cut in consecutive sections, and each section examined and duplicated by an exactly proportioned and magnified counterpart in wax. The subject under investigation is then built up to perhaps 100 times or more the size of the original, nerves, capillaries, etc., being all readily traced through to their origins.

Once the section has been cut further treatment becomes necessary in many instances before it is ready for examination. The celloidin or paraffin wax must be removed and the object stained to render it visible and to differentiate structure. The stains employed are mostly aniline derivatives, and are selected according to the tissue, as certain stains affect the different cellular contents in differing manners. The discovery of this property by Cole about 1880 made possible the differential staining universally employed to-day, which permits the observer to distinguish tubercle bacilli from surrounding tissue, nuclei from cells, different structures one from another in botanical, zoological and all other tissues.

For the frozen unstained specimen, yeasts, pond life, etc., dark ground illumination is usefully employed; for opaque subjects such as metals, and where high magnification is needed, the vertical illuminator, in which a transparent reflector is mounted behind the objective, which is made to serve as its own condenser; for crystals, geological specimens, starches, etc., the polariser and analyser.

The reader must not conclude from the foregoing that all specimens need special treatment for examination under the microscope, as this is far from being the case, in fact the greater number of specimens available to him require no special preparation at all unless it is desired to mount them for permanent record. Diatoms, foraminifera, algæ, the whole range of pond life, entomological and the majority of botanical specimens, can be taken direct to the microscope or collected during the summer and stored for classification and examination during the winter evenings, while if the microscope user is prepared to maintain a small aquarium (a Leclanché cell jar is in many instances sufficient) he can grow his specimens and find endless interest in their life cycles, and have living material available for examination at any time.

From a near-by pond, ditch or well, enough material can be collected to give entertainment combined with new insight that will last for many days. Simple but suitable materials are essential—some bottles, a few small corked phials, an extensible stick or rod to which can be attached at the far end a hook or a net. A pocket lens enables a rough idea of the " catch " to be formed from time to time. When the sorting out takes place at home many kinds of interesting creatures will be found. It may be that some of the lowliest forms of life will be seen—just minute pieces of jelly, the amœba endowed with life and exercising the means of existence, so mysterious yet so absorbingly attractive. Or higher in the scale of life are protozoa which swim by the movement of exquisitely fine hairs, secreting smaller organisms as they come their way. Then there are wheel animalcules of great variety, spinning their way from place to place in the very limited field of the microscope, and so more and more highly developed creatures will be found, still infinitely small, yet possessing circulatory systems and means of digestion and locomotion. There is a little creature who is architect, brickmaker and mason ; as you watch him you may see him produce the bricks in the form of little pellets, with which he builds the casing or house in which he dwells, fastening them in position with a waterproof cement of his own invention. To add to his attraction some fine hairs or cilia emerge from the top of his little dwelling and exhibit a continuous movement which whirls his prey into his digestive system.

There are several other varieties that use the whirling cilia for engulfing the prey suited to their appetite and digestive capacity. The beauty of the movement and the translucence of the creature form a never forgotten attraction.

There is a " bell " animalcule that has a coloured ball-like head, which continually rises and falls, connected to a more substantial piece of weed by a thread-like tube ; in the course of its motion it secures its needful sustenance. More wonderful still are the " Diatomaceæ," not so much on account of their life history but because of their structure. They are to be found in abundance in river and sea, in an endless variety of kind and form. So intricate and minute are the " markings," as the structure is termed, that the utmost skill with the highest magnifying powers is necessary to see some of it, and then the interpretation is controversial. So, with simple means, enthusiasm, a quickly acquired manipulative skill, there lies at every one's door something worth gathering and examining. In the garden, leaves, insects, insect eggs, flower seeds, pollen, wings of insects (of which no two of different species are alike) are all grist for the microscope mill. Rambling at the seaside, the cliffs themselves will tell a story if a small piece is submitted to microscopic scrutiny, and every incoming and outgoing tide brings and leaves something that is interesting and worth seeing.

After the examination of the specimen the observer may wish to make some permanent record of his find, either for purposes of identification at a library or for the illustration of a paper. Two methods are commonly employed, drawing and photography—or, to be more correct, since the microscope forms an integral part of the apparatus, photomicrography.

Both these are susceptible of subdivision into various methods, but we propose to deal with the simplest and withal the most generally effective for the beginner, who will when more experienced select the method which seems best to fulfil his needs. We would emphasise that elaborate apparatus does not guarantee success (some of the most successful results we have seen have been achieved with simple means), and too often elaborate apparatus exposes and magnifies the user's deficiencies in technique. Begin with simple instruments, understand by trial and error the principles involved, and then proceed to more elaborate equipment as required.

*Drawing*—There are a favoured few to whom drawing freehand presents no fears, but they are the minority, and in recording microscopical observations accuracy, not only in the rendering of the picture seen but also of the magnification, is fundamental. The most accurate, simple and inexpensive method with which we are acquainted consists of virtually transforming the microscope into a projection apparatus. The structure is located visually in the usual manner. The microscope is then inclined to the horizontal position and care must be taken that the centre of the eyepiece is 10 inches away from the drawing block or table. A small 45° prism is then mounted in front of the eyepiece with one face as near as possible to the eye-lens of the eyepiece, but not in contact. The hypotenuse should be away from the eye-lens with the base of the prism directed towards the paper. A rather more brilliant illuminant should be substituted for that used in visual work and the drawing block shielded from surrounding light. The image formed in turn by the objective and eyepiece is reflected and projected downwards from the hypotenuse surface of the prism to the paper in the same manner as a picture is projected to the lantern screen. The observer then traces an outline of the image on his drawing pad in pencil and can colour in if desired.

This method can also be used with advantage in instructing any one not used to examining objects through the microscope, and indicating the structure to be observed.

*Photomicrography*—During the past 50 years a whole literature has grown up around this subject alone, and it may be sufficient to say that the microscopist can make it as simple or as elaborate as he wishes. Most people possess a camera of one sort or another, and from the simple box-form Brownie up to the most elaborate of focal plane miniature types, all can be pressed into service. One word of warning is necessary. The distance from the eyepiece to the surface of the film must be accurately measured. The observer when looking through a microscope refers the image to a distance of 10 inches, and all calculations of magnifications are based upon this fact. If the distance from eyepiece to film or plate is less, there will be a proportionate decrease in the magnification of the recorded image. This decrease can easily be calculated by the ratio of the known distance to the 10-inch image distance. In all photomicrography as distinct from ordinary photography success is not only dependent upon exposure, development, etc., but also upon accurate colour filtering. Special colour filters having microscopically accurate colour transmissions are made, among others, by Ilford, Ltd., Kodak, Ltd., Watson & Sons, Ltd., and these have been specially developed for photomicrography and advanced research work. Separate descriptive bulletins as a guide to their proper use are published by these firms.

For detailed instruction in photomicrography, using the ordinary hand camera in conjunction with a microscope, the reader is referred to the publication by Kodak, Ltd., London, which can be obtained gratis on request.

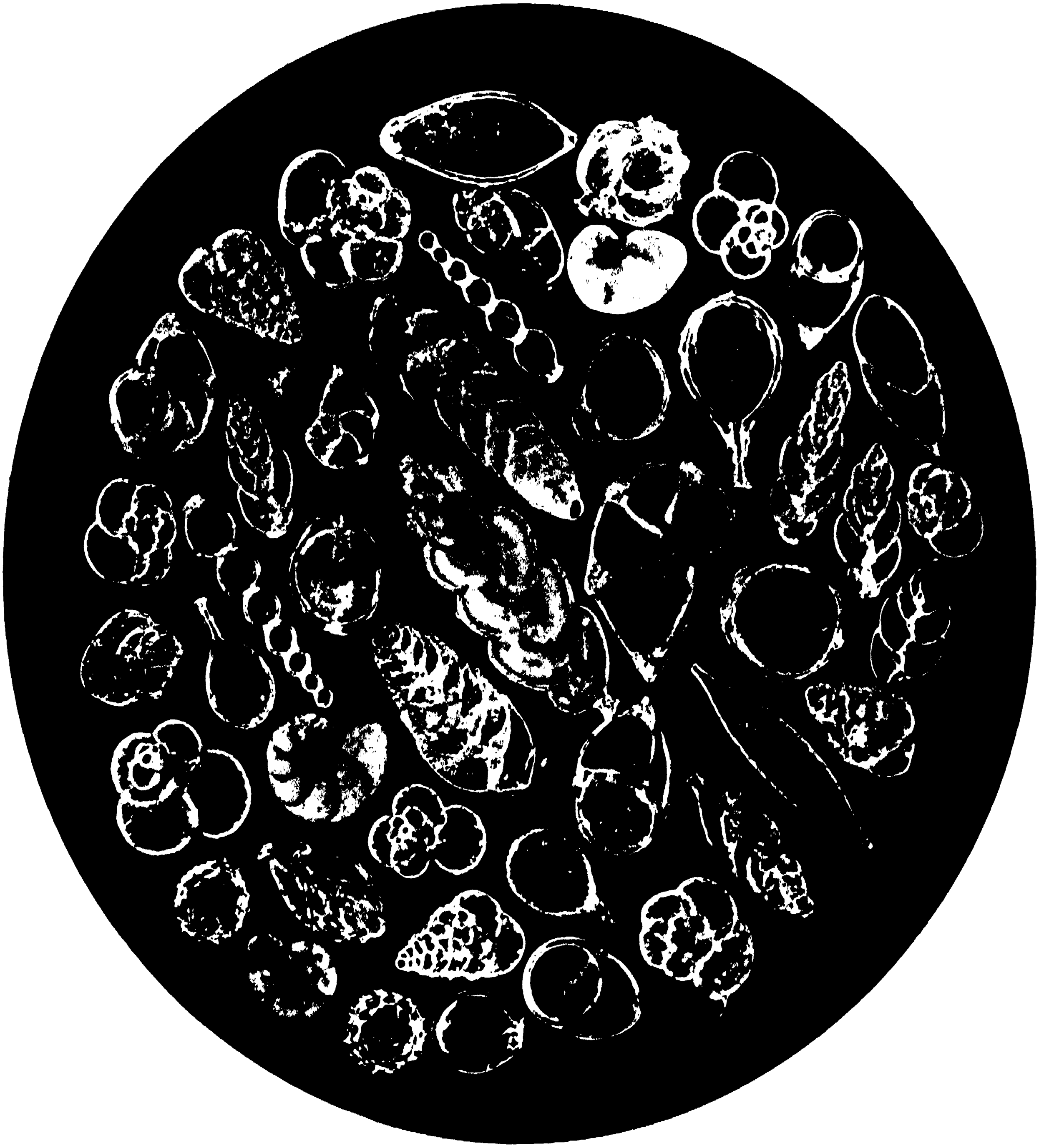
Generally, in scientific work, recourse is made to drawing rather than photomicrography when time is not too pressing a factor. The reason is not far to seek. The depth of focus or penetration of a high power microscope objective is small. The human eye by virtue of its power of accommodation, and the observer himself by means of the fine adjustment to his microscope, can overcome this drawback, and in drawing fill in the different planes, giving a complete picture as actually presented to the eye. The camera lacks this convenience and the record is consequently of one plane of focus only.

If this book has succeeded in holding the interest of the reader, in stimulating a wish to pursue the matter further, he is recommended to read the books already mentioned. Pursued as a hobby he will find that the microscope unlocks unsuspected doors, widens the outlook upon the world, stimulates the designer, and to all provides recreation in the real meaning of the word and a complete surcease from the daily anxieties.

Owing to the rapidly increasing number of adherents to microscopy the Microscopical Clubs and Societies have taken on a new lease of life, and there are many groups situated in the different larger towns of the country. There are others also who, having experienced the pleasures afforded by microscopy, are willing to initiate those who desire to learn how to use their instrument and to gain the best results from the equipment in their possession.

*The writer will be glad to give the names of the secretaries of the various societies or clubs nearest to any inquirer, or the name and address* of any one within a reasonable distance who is willing to guide and advise would-be microscopists who wish to probe further into the beauties and marvels of the world of nature revealed through this New Vision.

W. WATSON-BAKER.

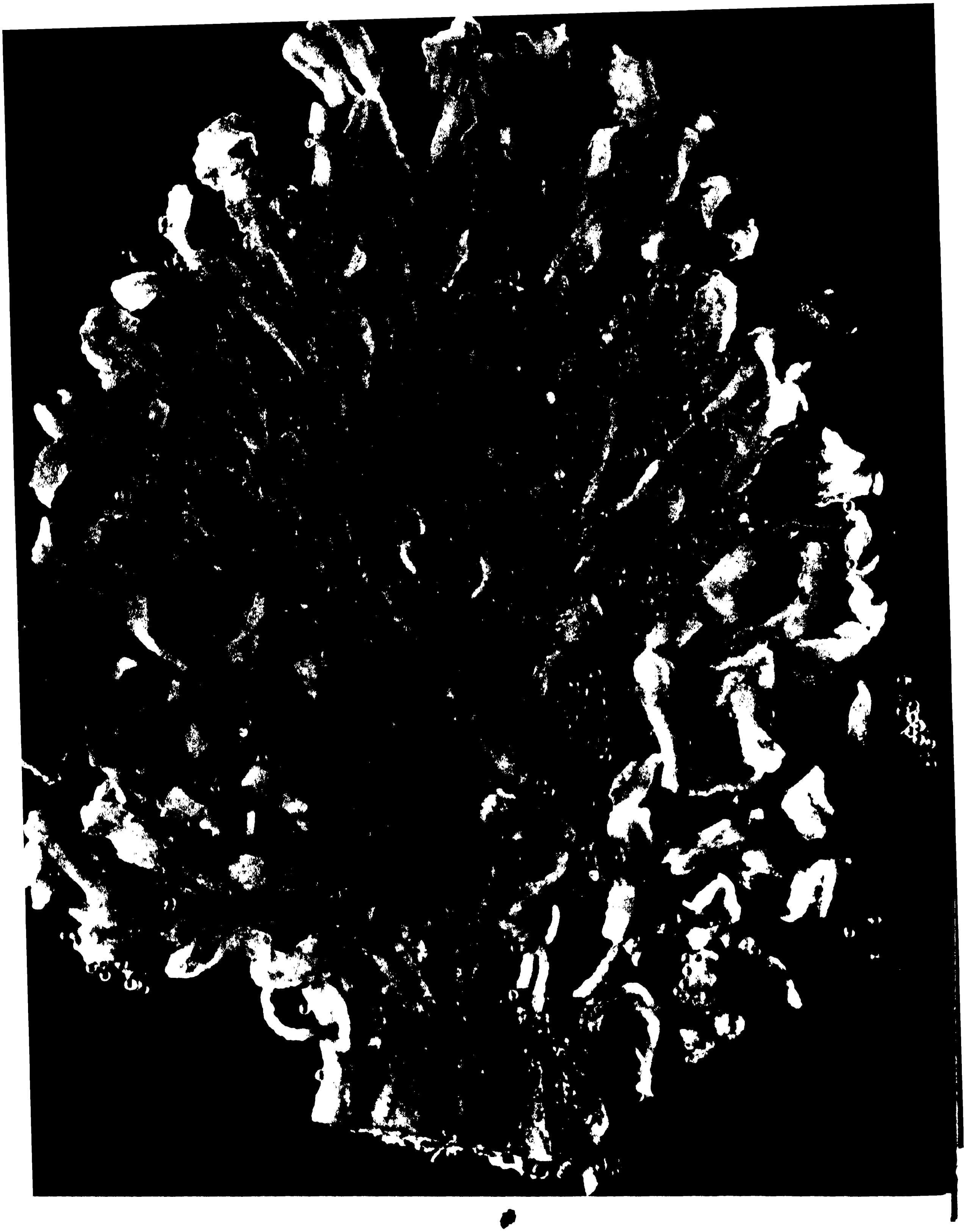


1. FORAMINIFERA (Chalk Shells).

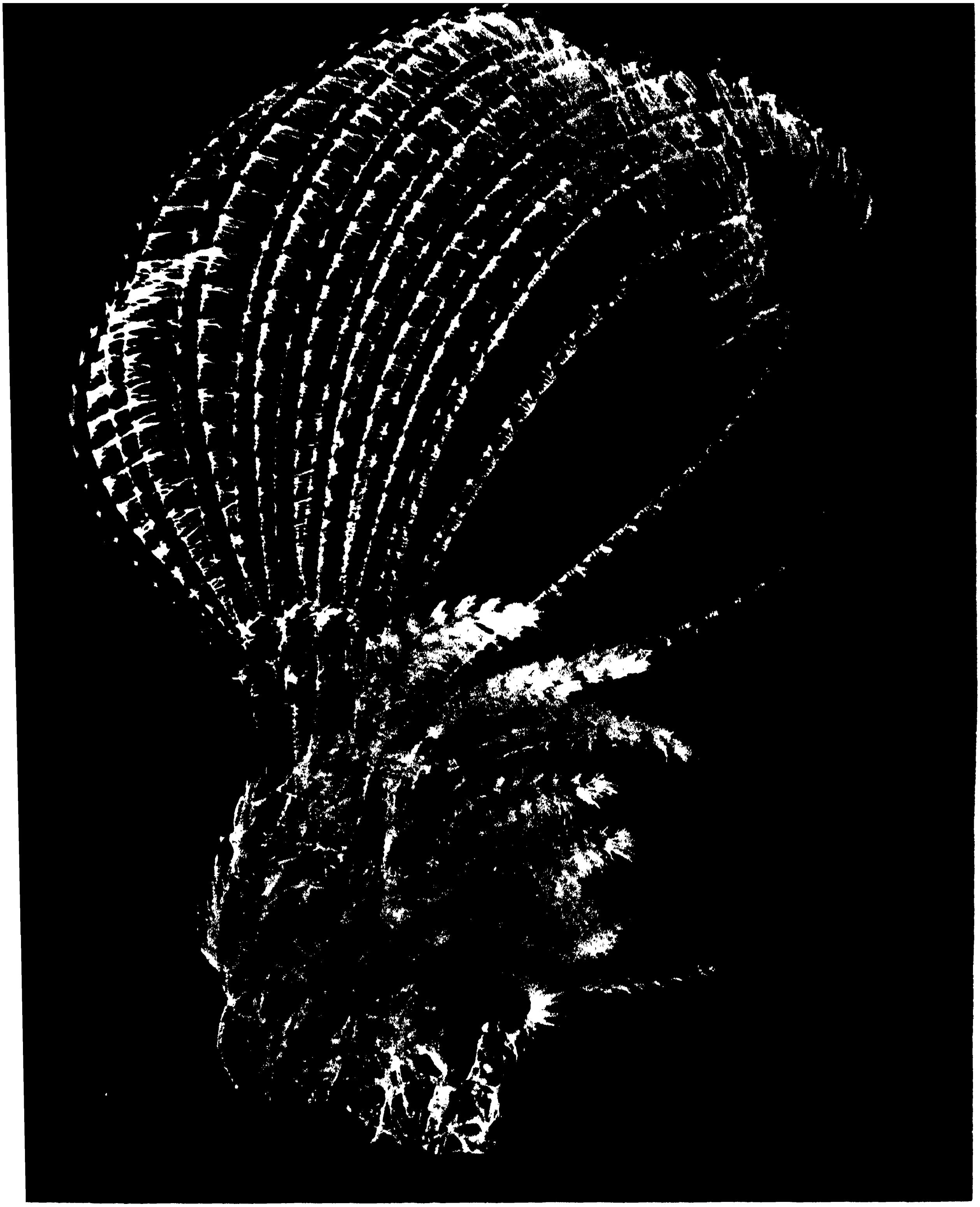
Pattern of countless individualities of form becomes the mass of chalk cliffs and limestone mountain ranges. In shallow seas, along the coast, these tiny organisms live in fanciful chambers of lime.

2. POLYCISTINA (Fossil Shells)— opposite.
The delicate shapes, as of carved ivory, are fine in workmanship, strong in structure—full, as one sees, of character.

3. SHELL OF A SEA URCHIN.
The modern sculptor must envy the massiveness of form, the grandeur of contour, of this small shell, whose dove-tailing structure makes a strange and interesting pattern.

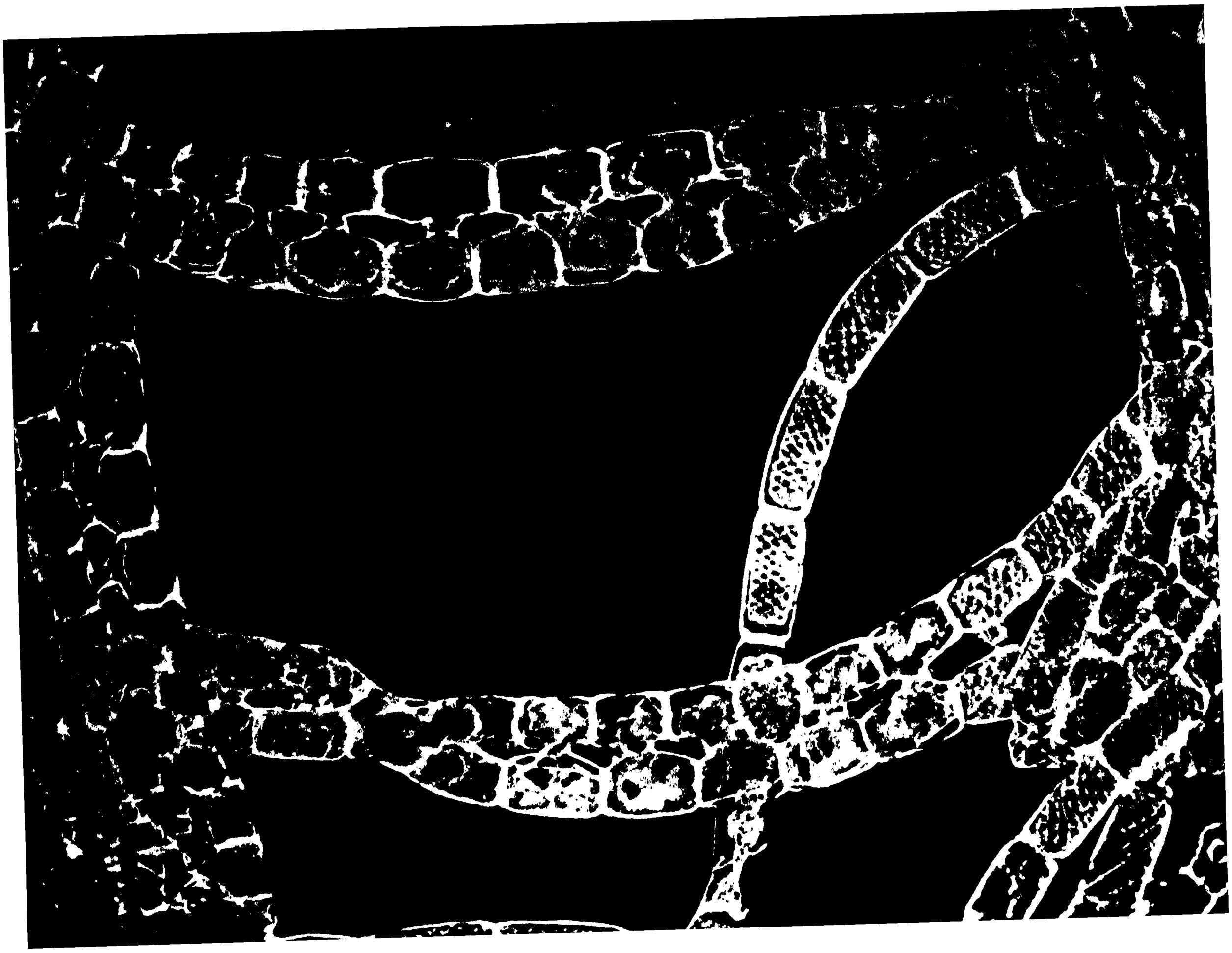


4. POLLEN OF HOLLYHOCK. The pollen grains hang like fruit upon a fantastic tree.



5. FILAMENTS OF BARNACLE.

The temptress plumes of the barnacle create a current in the water, and draw food to it. One would say a fan or headdress of delicate form, the adornment of imperial beauty.

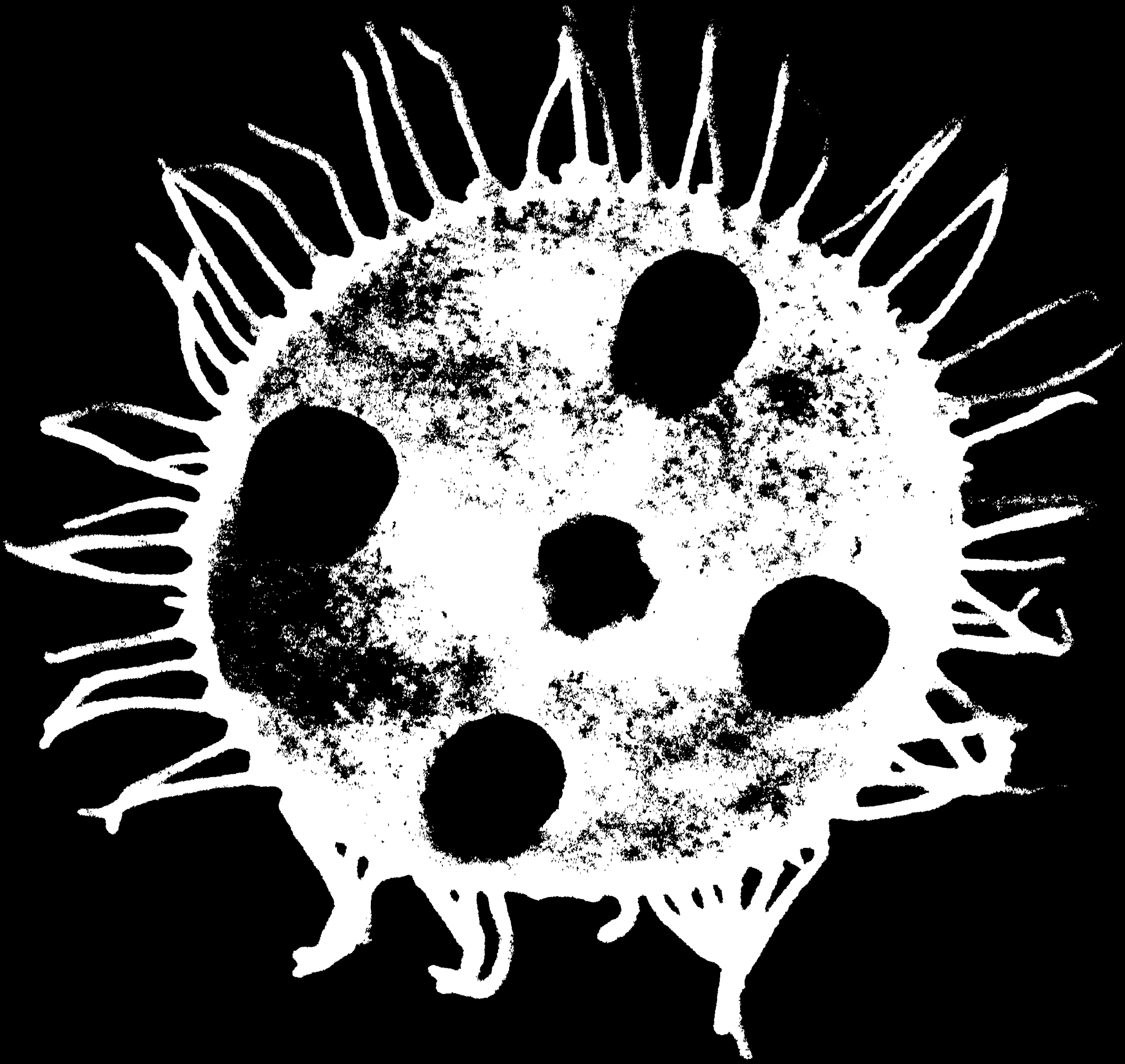


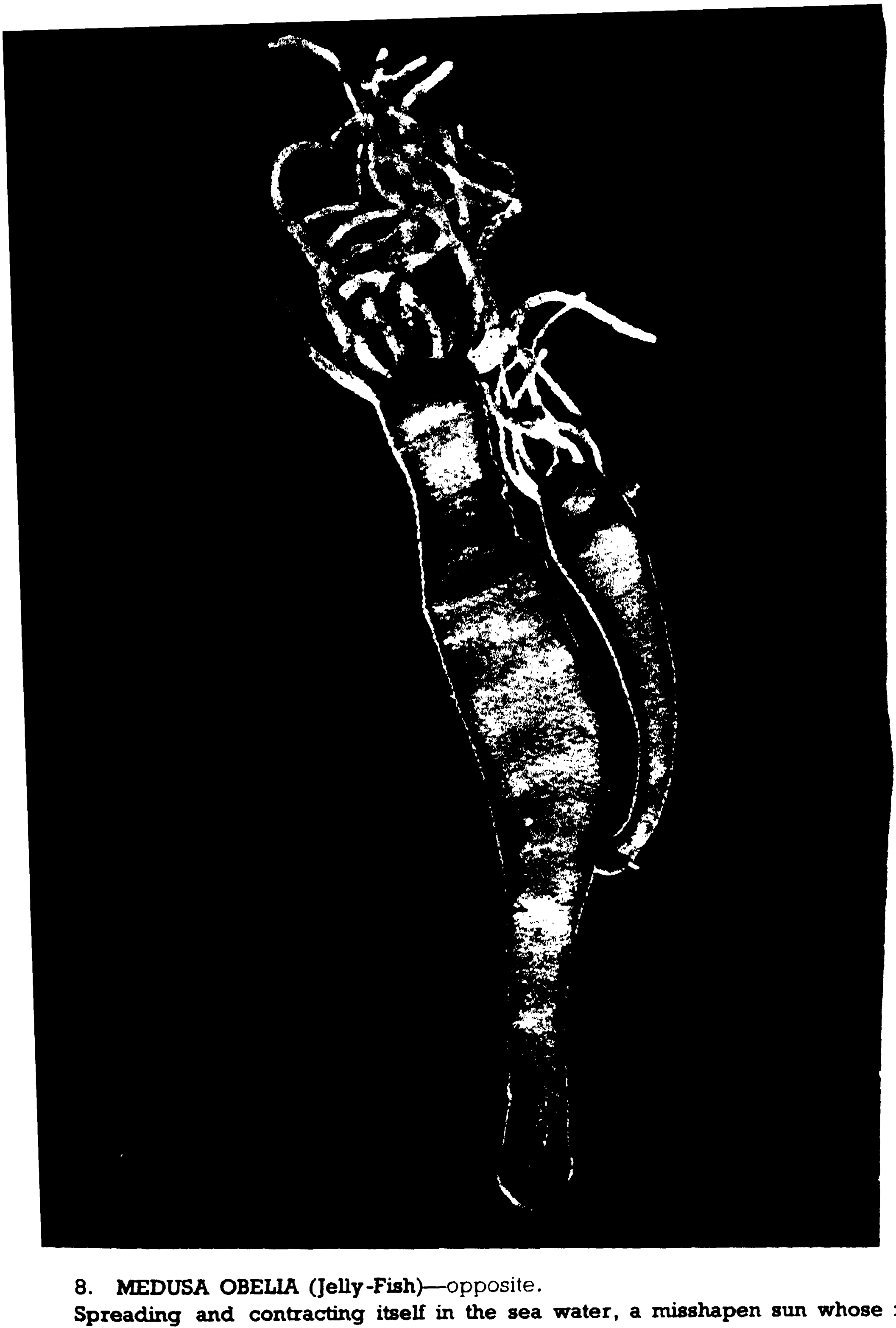
6. SPIROGYRA (Water Plant).

The slime of a pond takes shape beneath the magnifying eye into bracelets of brilliant green, whose spiral cells pass from one to another in accordance with the mysterious affinities of nature.

7. SPONGE SPICULES—opposite.

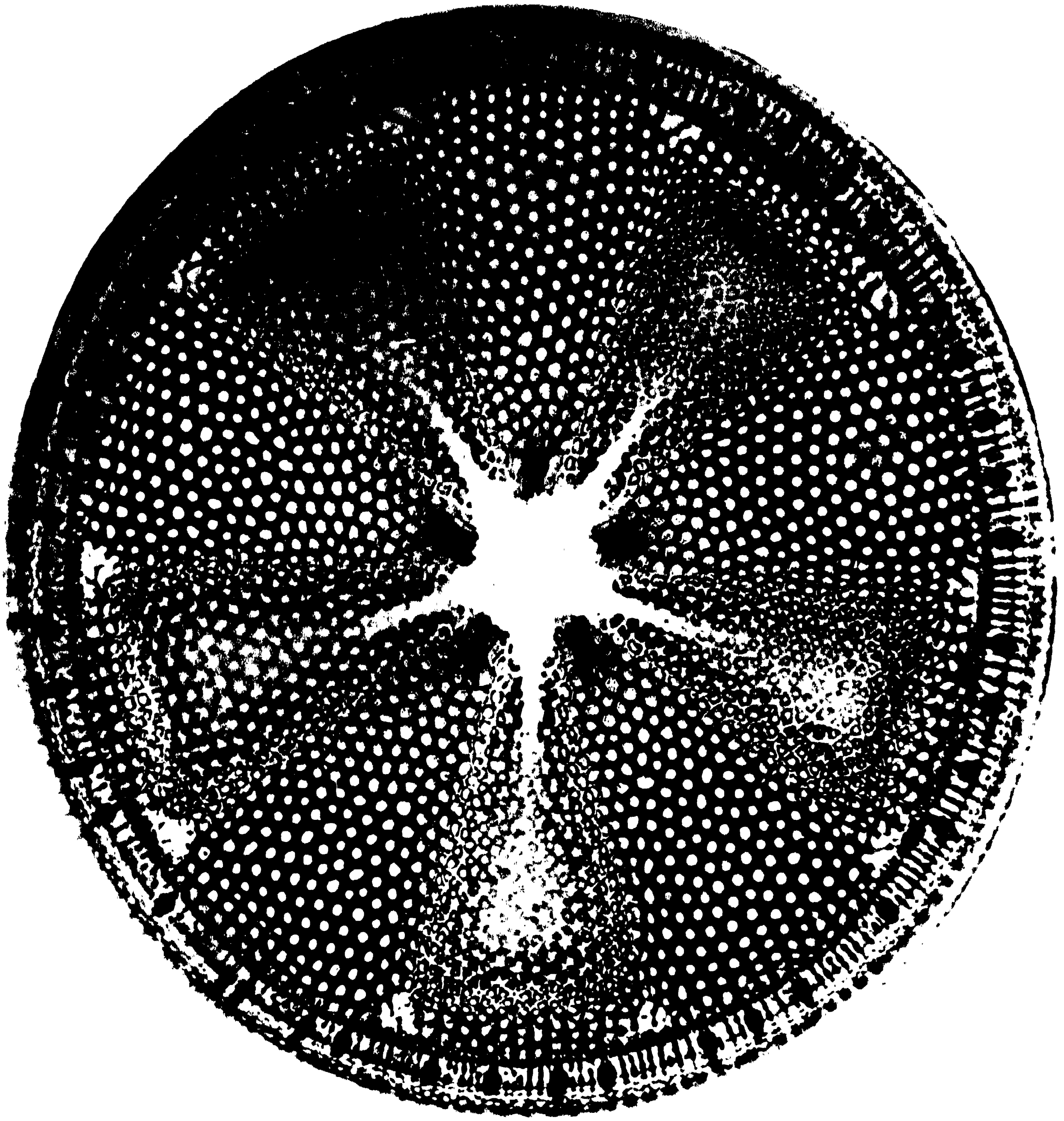
The lavish invention of nature is manifest in a granule of sponge. Has the abstract painter of to-day achieved anything more interesting than this evolutionary design ?





8. **MEDUSA OBELIA** (Jelly-Fish)—opposite.
Spreading and contracting itself in the sea water, a misshapen sun whose rays are threads equipped with darts, that stab minute prey, the medusa turns to our gaze a diagrammatic surface.

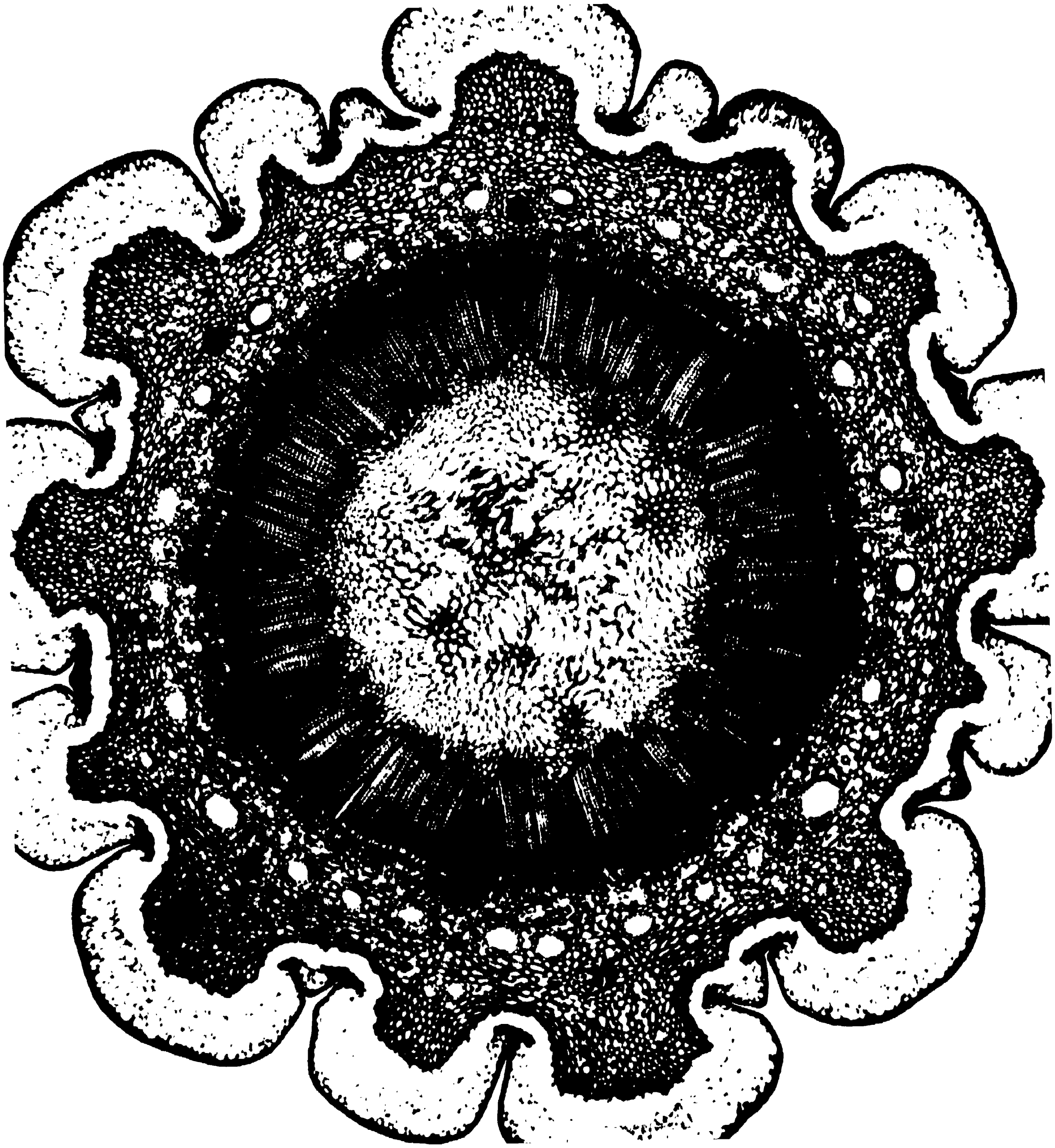
9. **HYDRA** (Fresh-water Octopus).
In streams and ditches the hydra is found, its tentacles reaching out for food. Parthenogenetically it produces its young. The microscope eye reveals to us the birth of a hydra.



10. DIATOM, Actinoptychus Metii (Vegetable Organism).

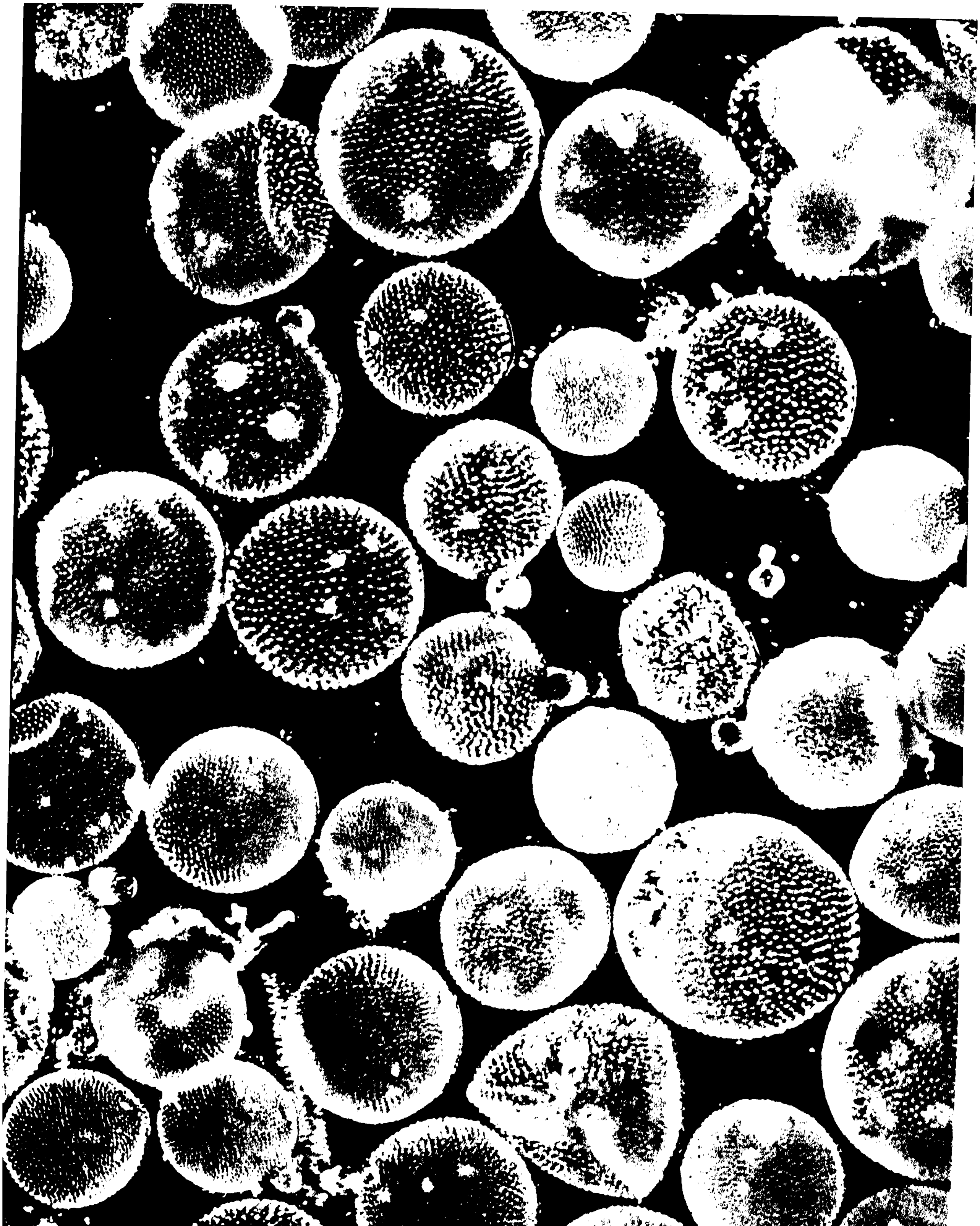
The photograph from which the reproduction was still further enlarged was taken at a magnification of four hundred diameters. Like some Byzantine enamel the diatom emerges from the ooze.

11. SECTION OF THE STEM OF A SPRUCE FIR (Picea Excelsa). The age of a tree transmutes itself into a pattern of rings. The dead cells are the outer layer ; within is the living wood, where globules of protective resin fringe the inner ring.



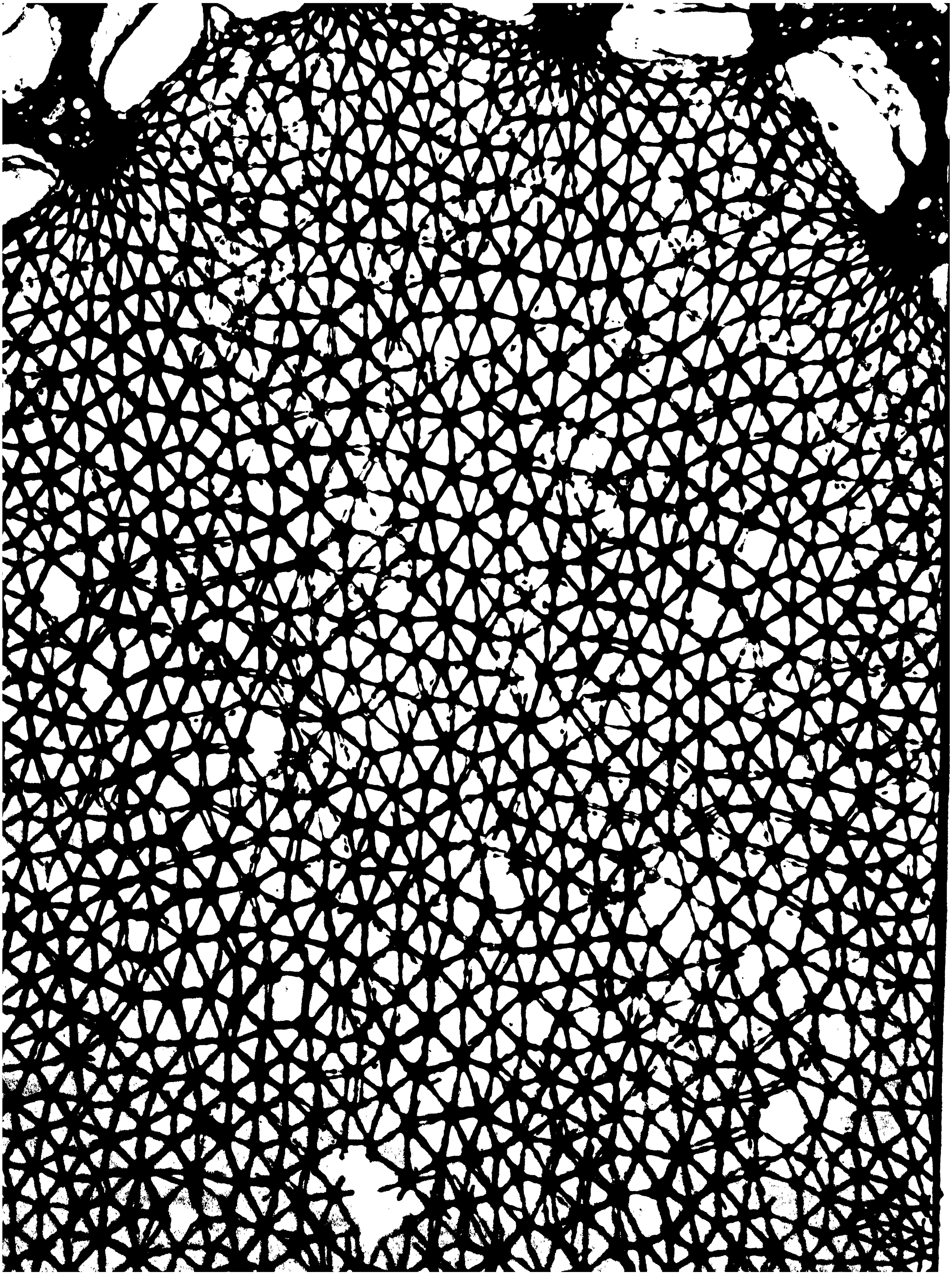
12. LOPHOPUS (Water Organism).
Like a beaded flower the lophopus spreads its filaments in search of food. A digestive process. A thing of beauty.

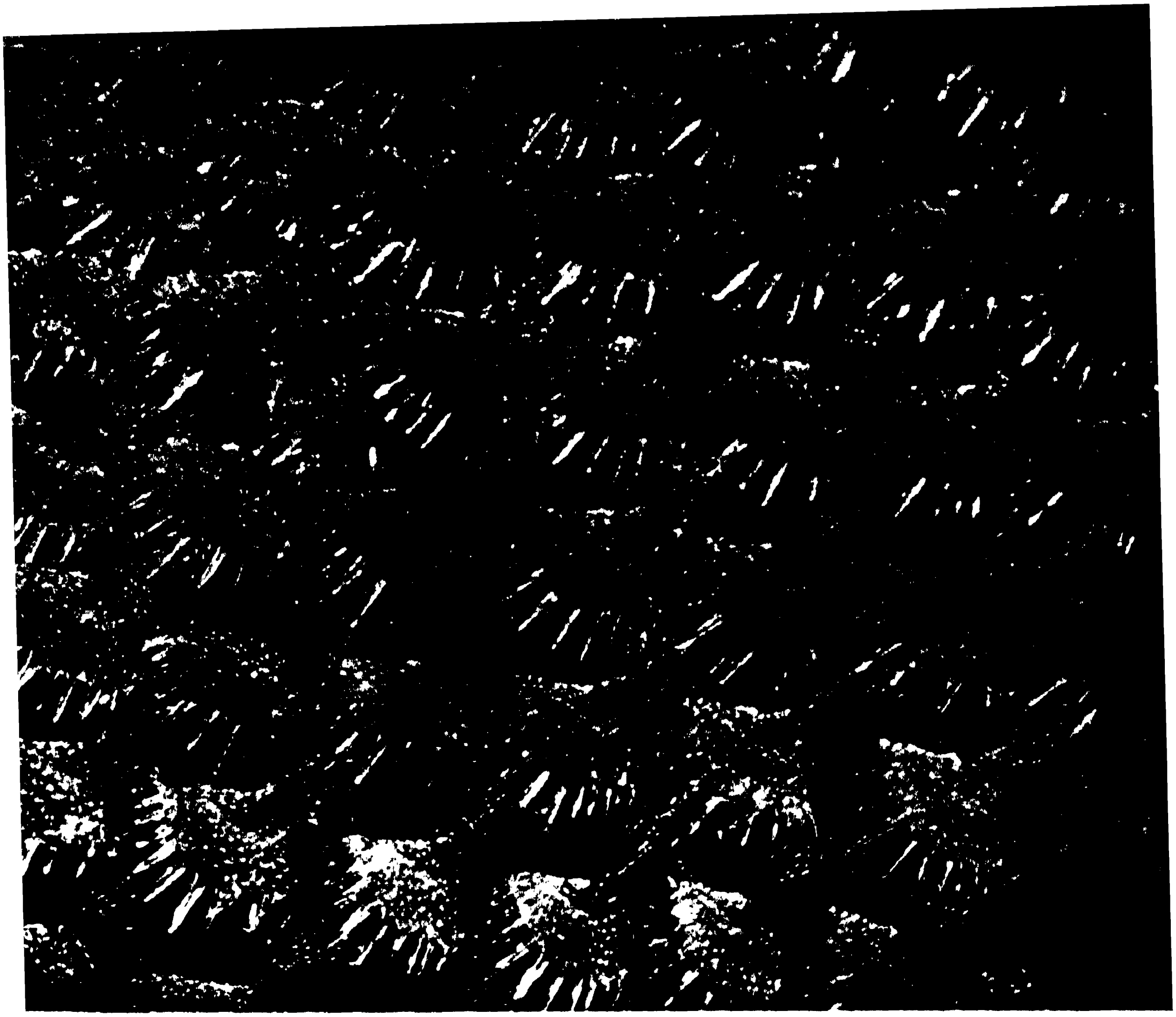
13. VOLVOX GLOBATOR (Water Organism)—opposite.
The drama of protoplasm becomes a pattern. These bright green globules carry within them fresh cells which split away when ripe, forming a myriad new spheres.



14. PRAYING MANTIS.

HEAD OF A HOUSE-FLY.





16. STEM OF A RUSH (Juncus)—opposite.

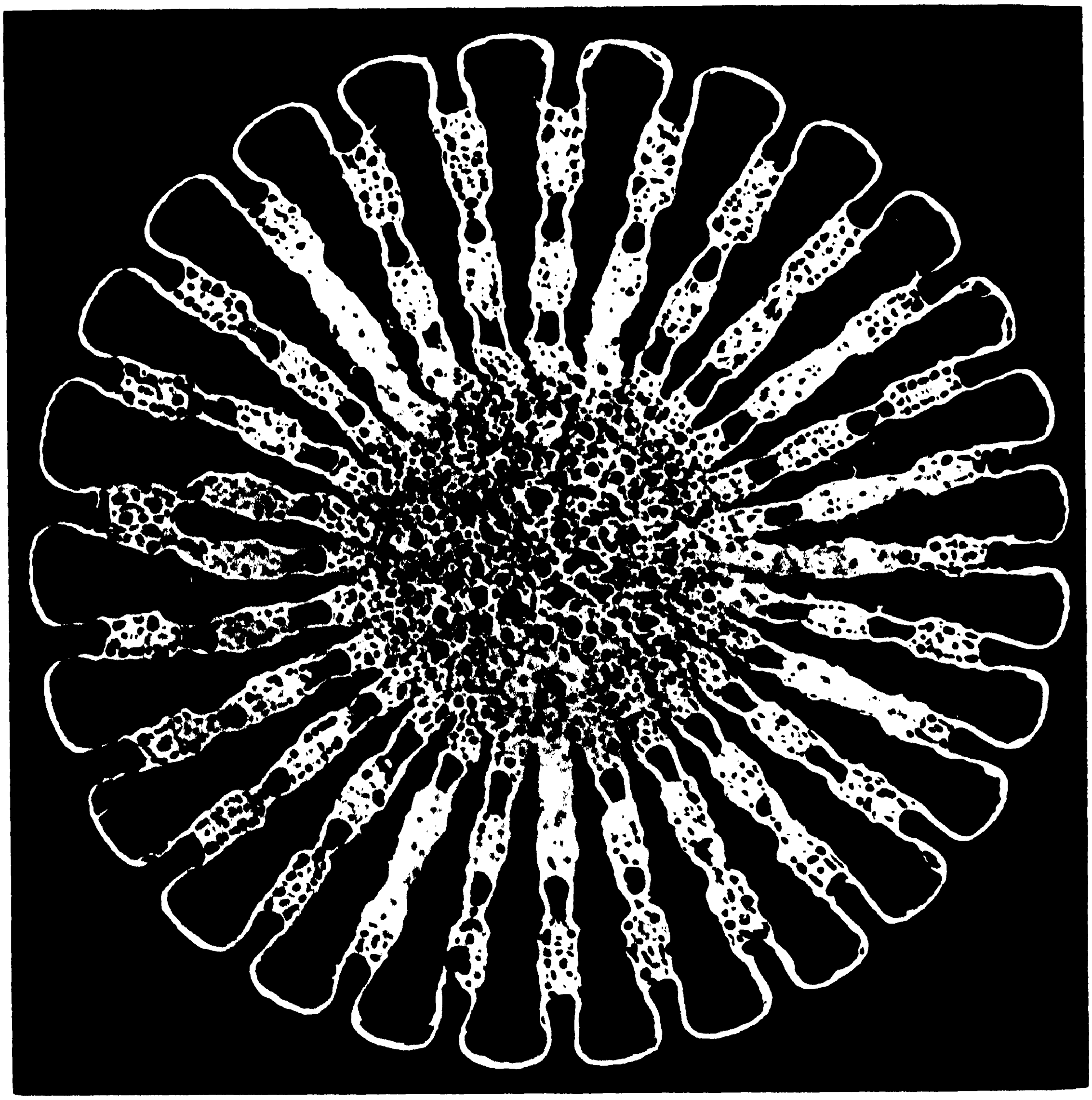
A plant growing in marshy ground breathes under water. Air is stored in its intercellular space. Hence in section it shows this delicate tracery, so attractive to the eye because so varied.

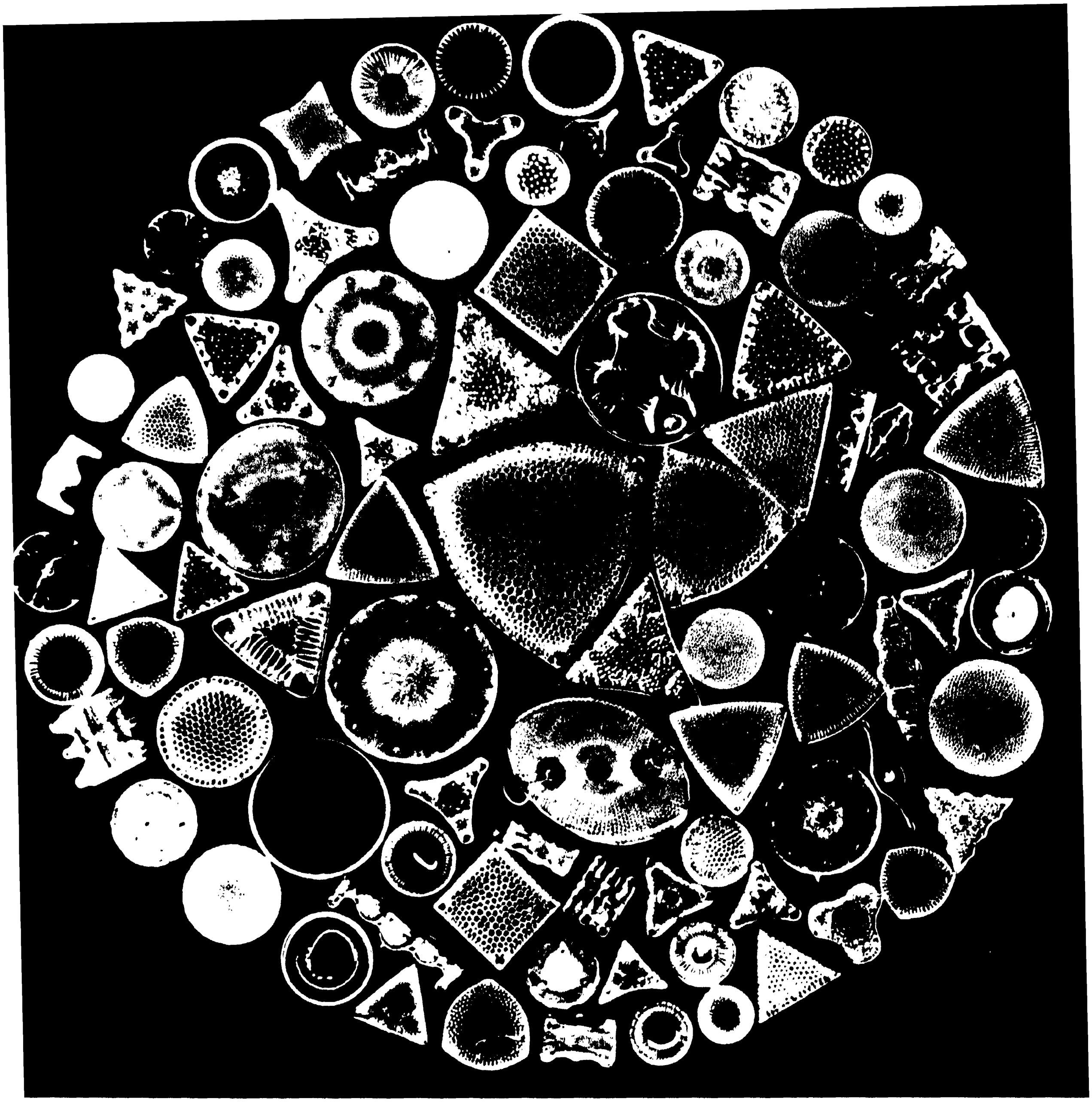
17. SKIN OF A SOLE.

The shape of the scales, with their interesting ribbing and dovetailing, should be observed. The mounting of tiles on a roof is not more effective than nature's original pattern. These scales serve to strengthen the side of the fish, and to protect it against the weight of water.

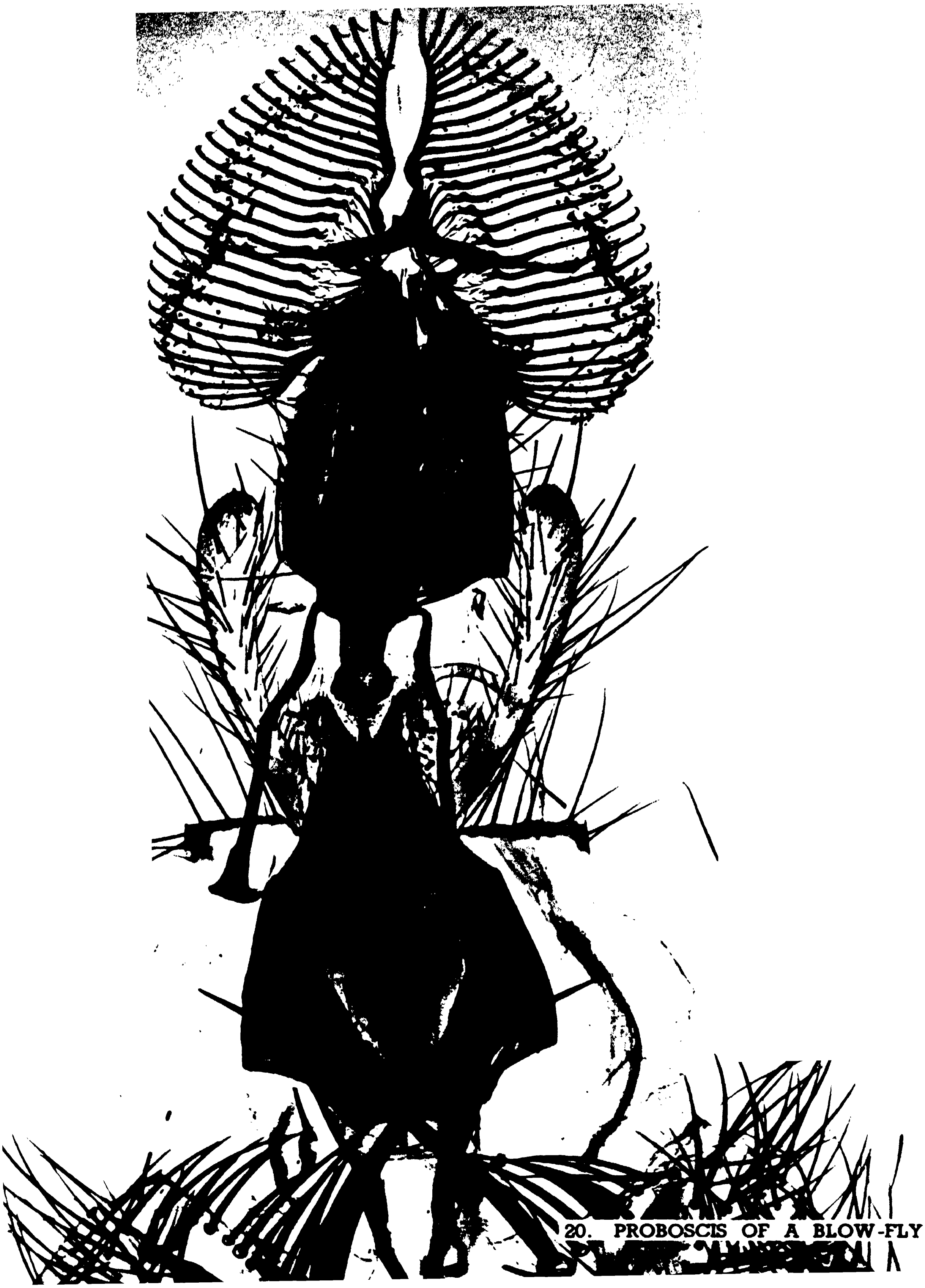
18. SPINE OF ECHINUS.

These spines are the projecting lumps which are to be found on the shell of any sea-urchin. The photograph is of a cross-section through one of them. The provision for circulation to keep the shell healthy, and all the beauty of the interlacing, is remarkable.

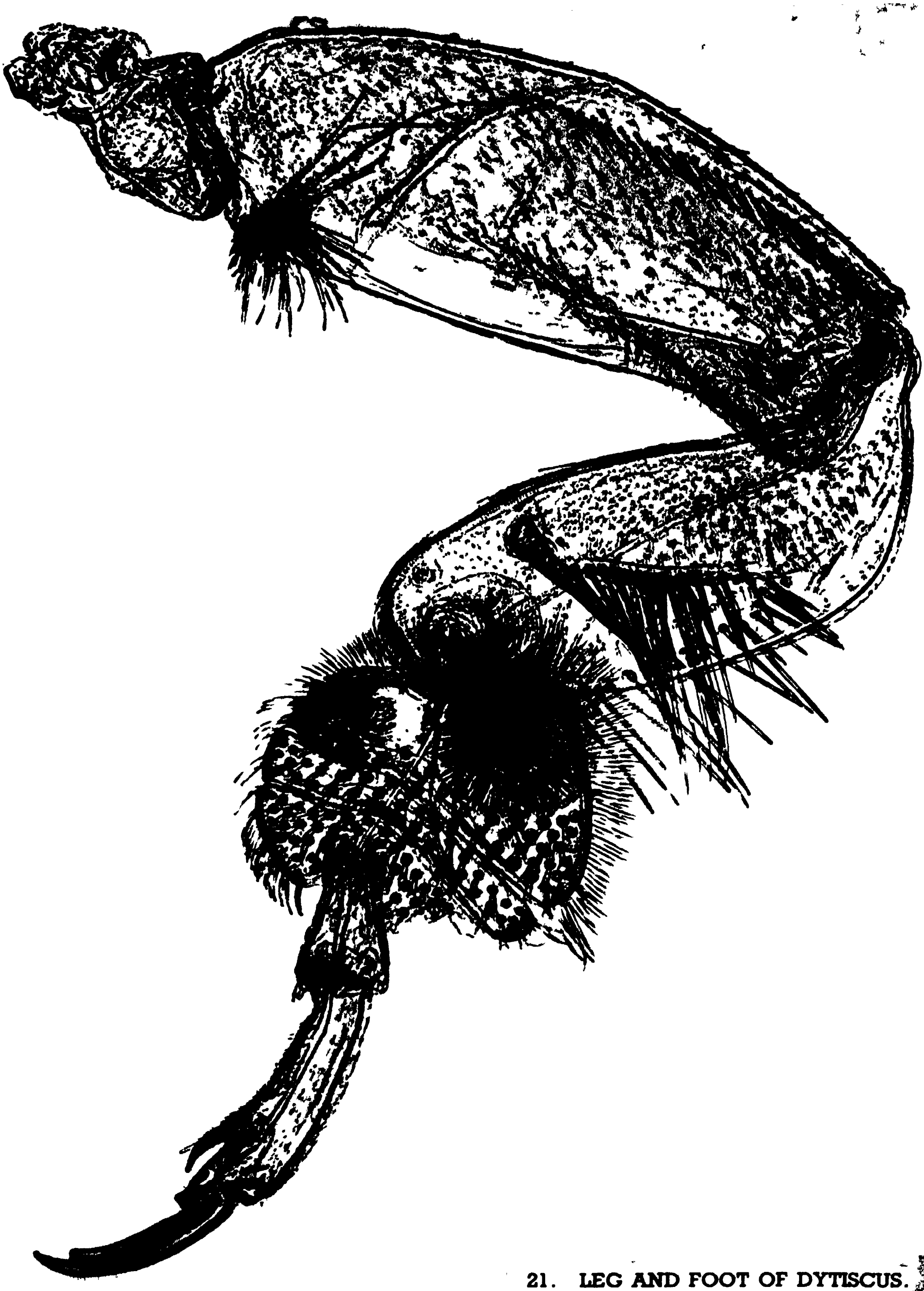




19. DIATOMS.

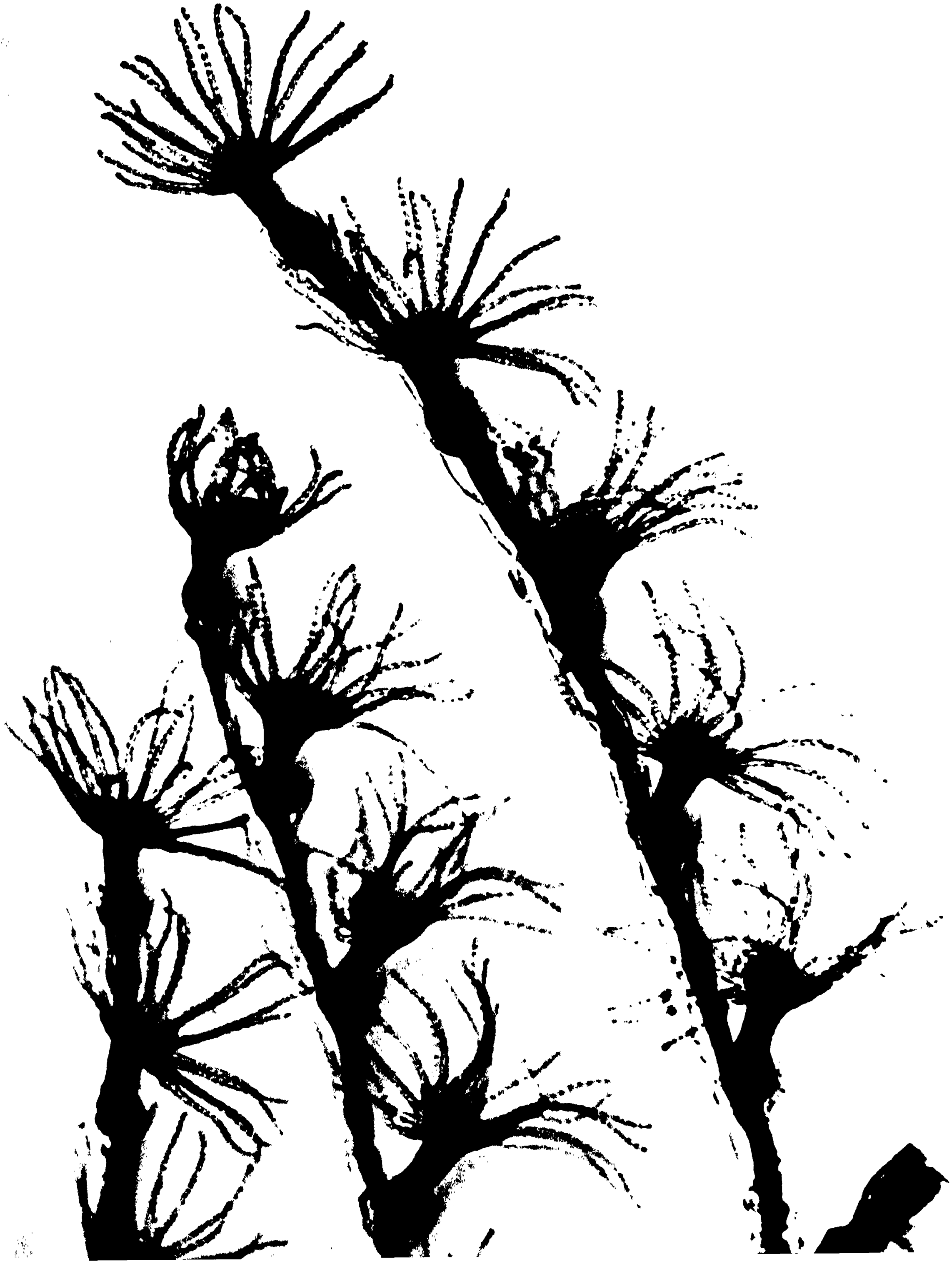


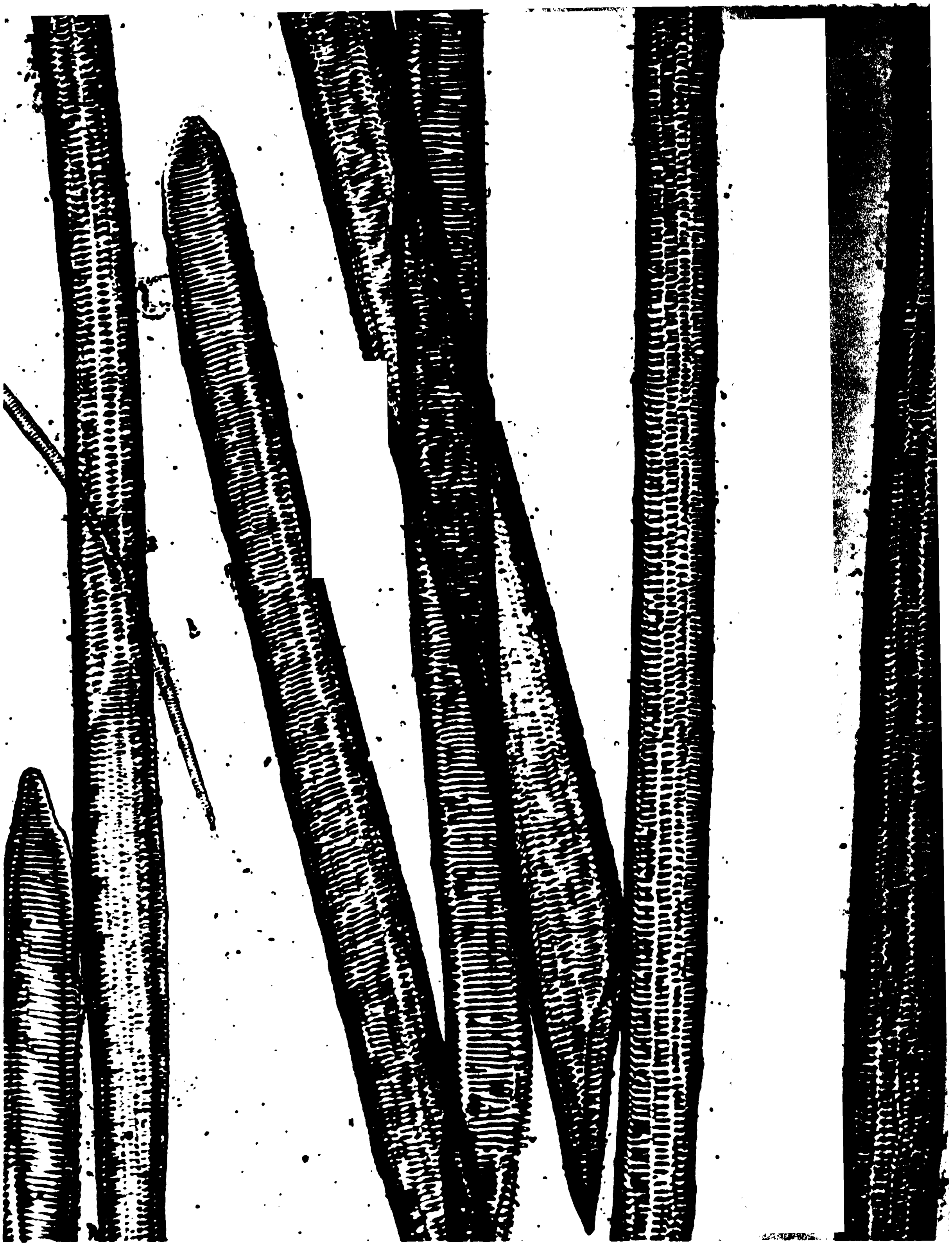
20. PROBOSCIS OF A BLOW-FLY.



21. LEG AND FOOT OF DYTISCUS.

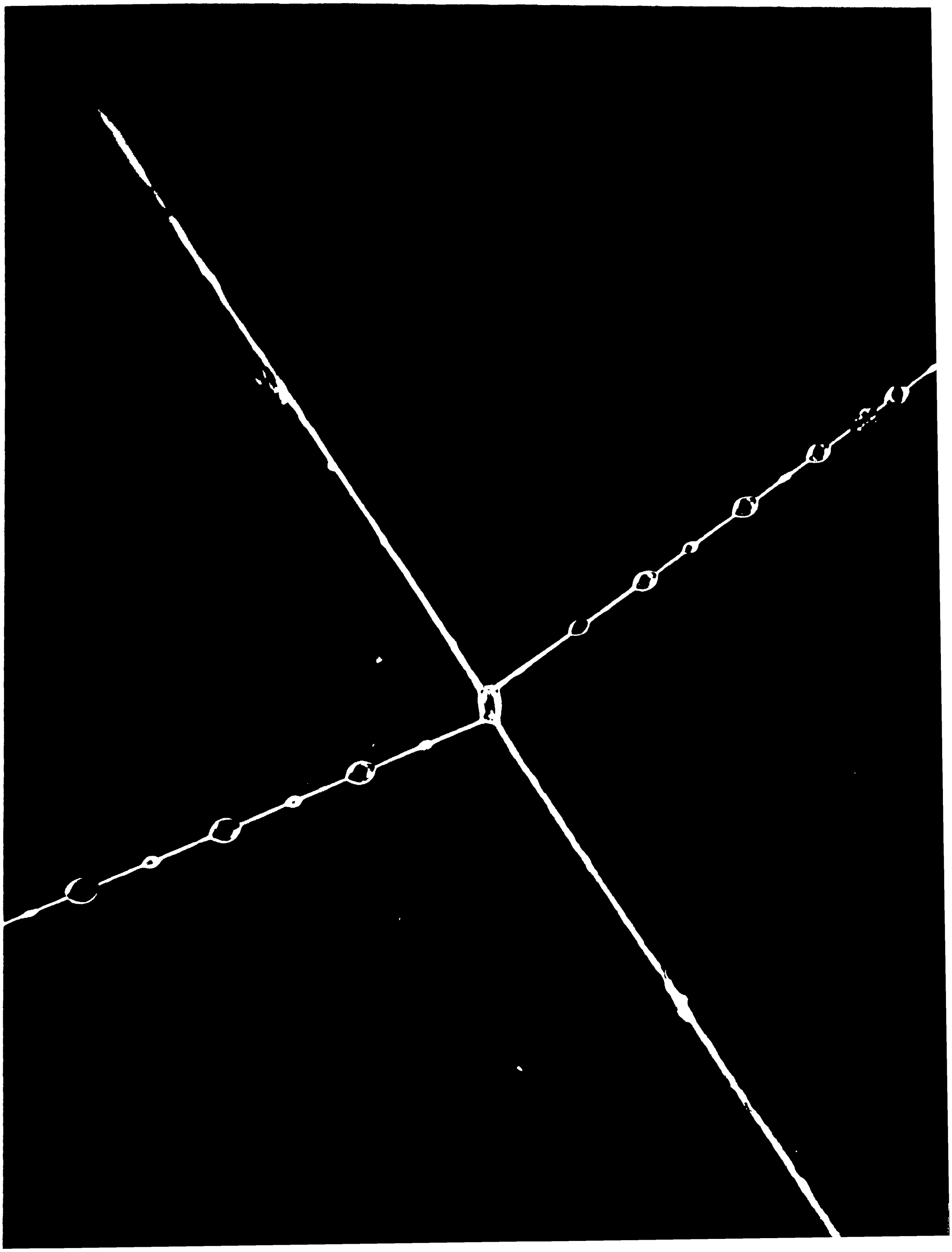
22. Part of a living colony of MARINE HYDROZOA, showing the expanded Polyps with their tentacle-crowned heads.





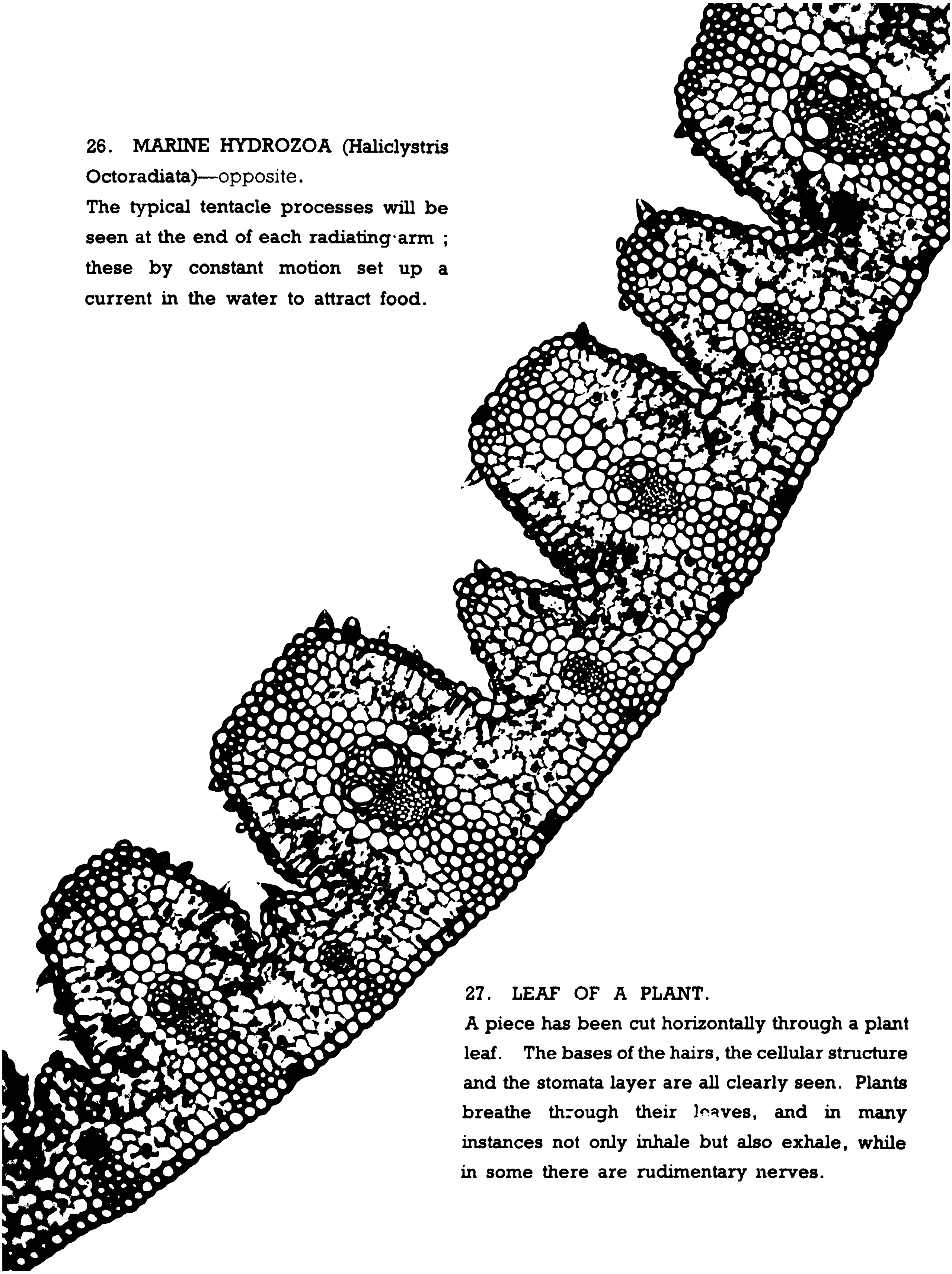
23. SCALARIFORM VESSELS. This structure usually surrounds the woody vessels which convey the sap up the stems of ferns. It strengthens the stem against gusts of wind, and has a springy effect similar to that to be found in the protecting coils of a Bowden

24. COMBS ON A SPIDER'S FOOT—opposite. 25. SPIDER'S WEB.
The combs on a spider's foot are used to set up a vibration on the radial lines of the web, so causing the viscid fluid deposited on the circular lines to collect into droplets.



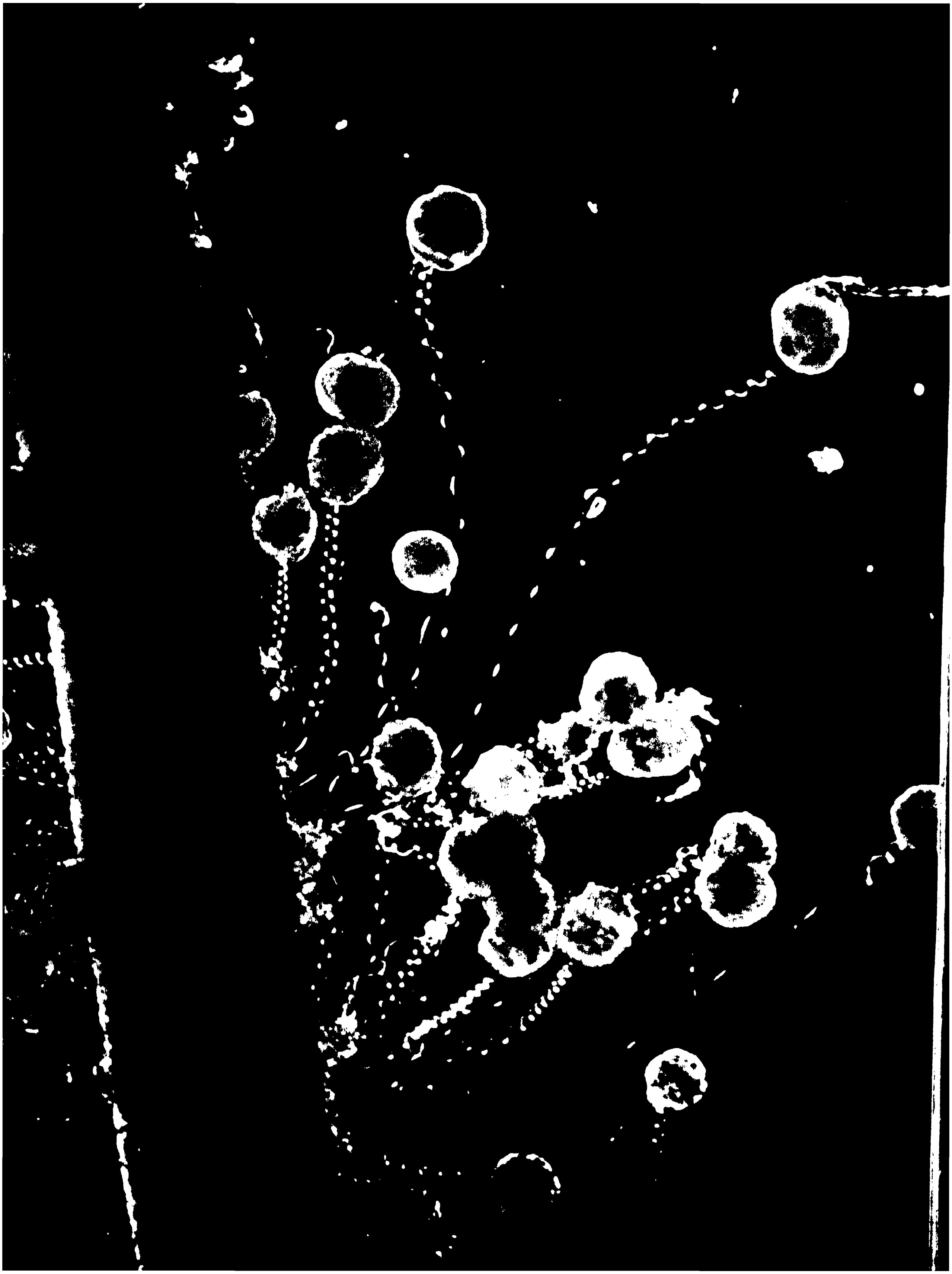
26. MARINE HYDROZOA (Haliclystris Octoradiata)—opposite.

The typical tentacle processes will be seen at the end of each radiating·arm ; these by constant motion set up a current in the water to attract food.



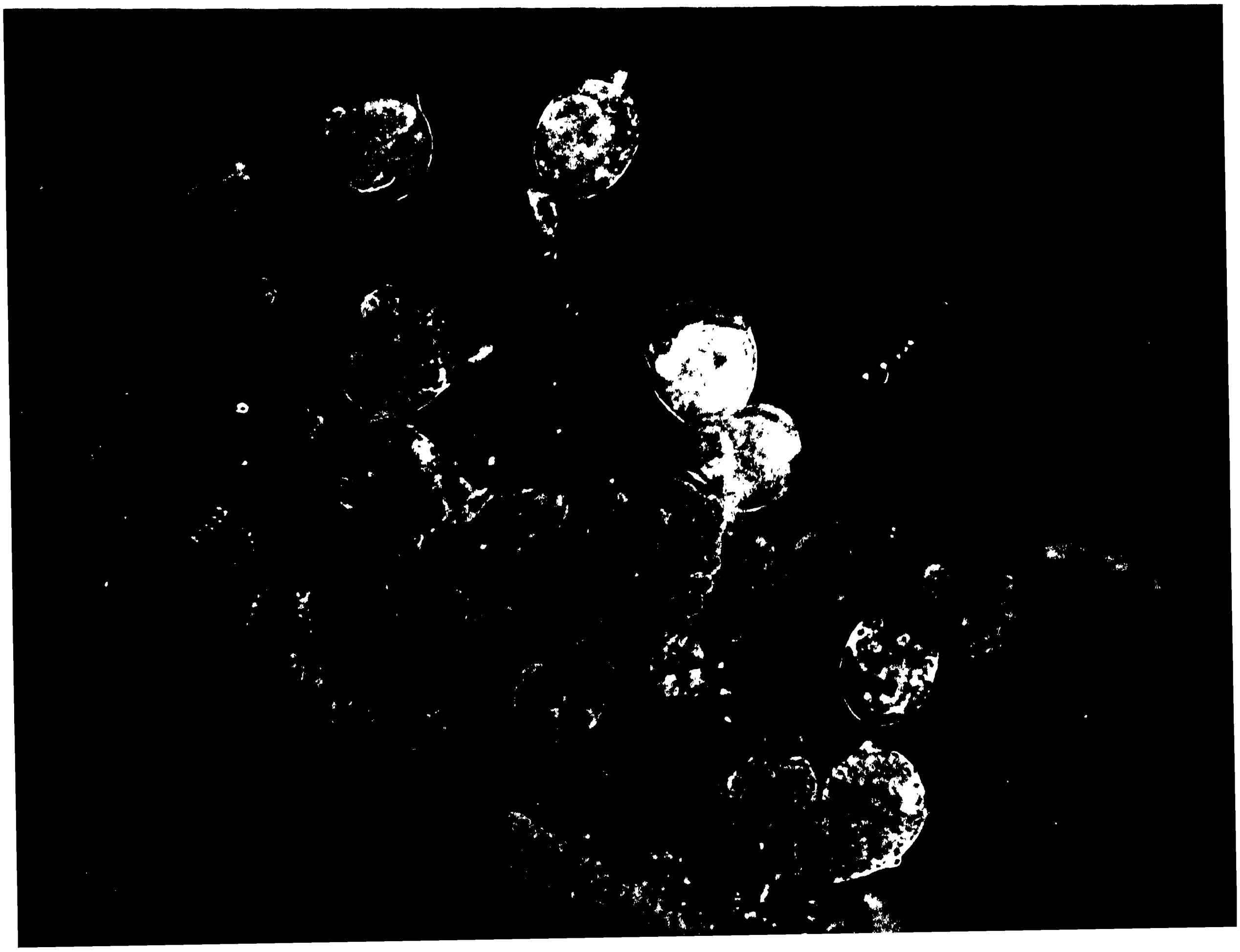
27. LEAF OF A PLANT.

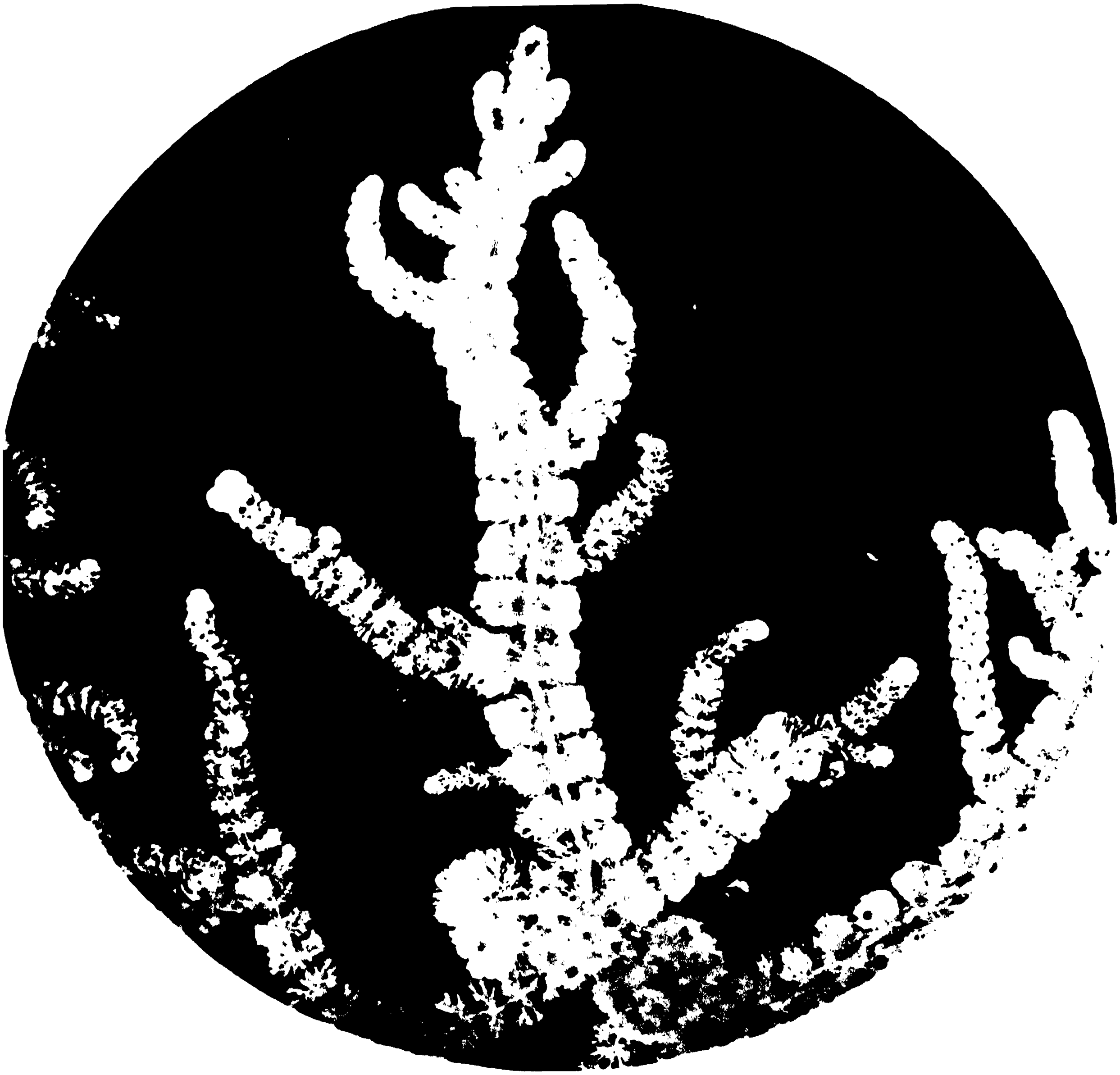
A piece has been cut horizontally through a plant leaf. The bases of the hairs, the cellular structure and the stomata layer are all clearly seen. Plants breathe through their leaves, and in many instances not only inhale but also exhale, while in some there are rudimentary nerves.



28 and 29. VORTICELLA.

This little plant, known as a bell animalcule, attaches itself to freshwater algæ or weed. The long filamentous process permits the bell-shaped head to be thrust forward, with the waving cilia setting up a current in the water to attract likely food. The moment this is found the mouth of the bell closes on it, and the animalcule retreats back on to itself to carry out the process of digestion. On this page it is seen photographed at a higher magnification and by a different technique.

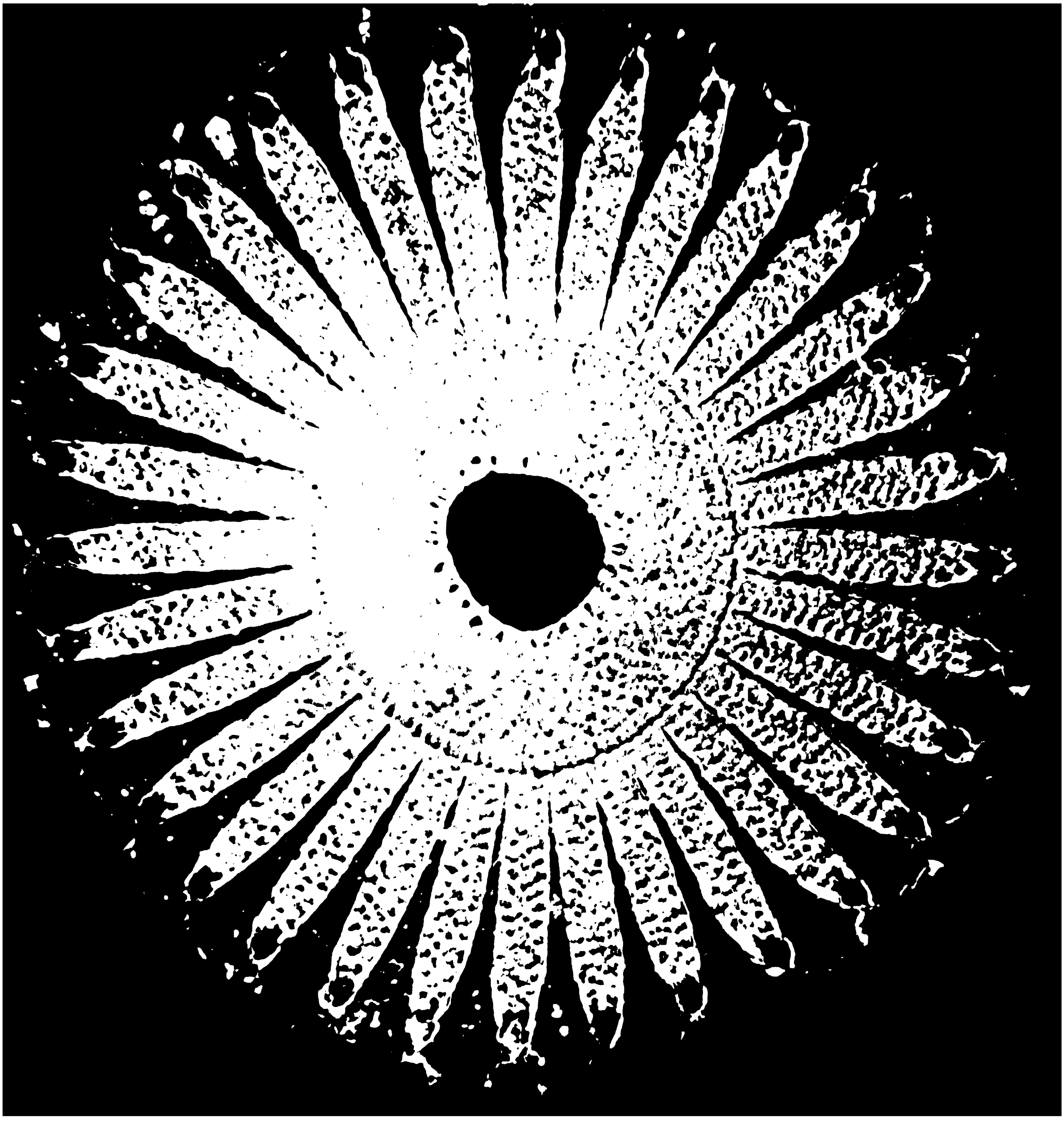


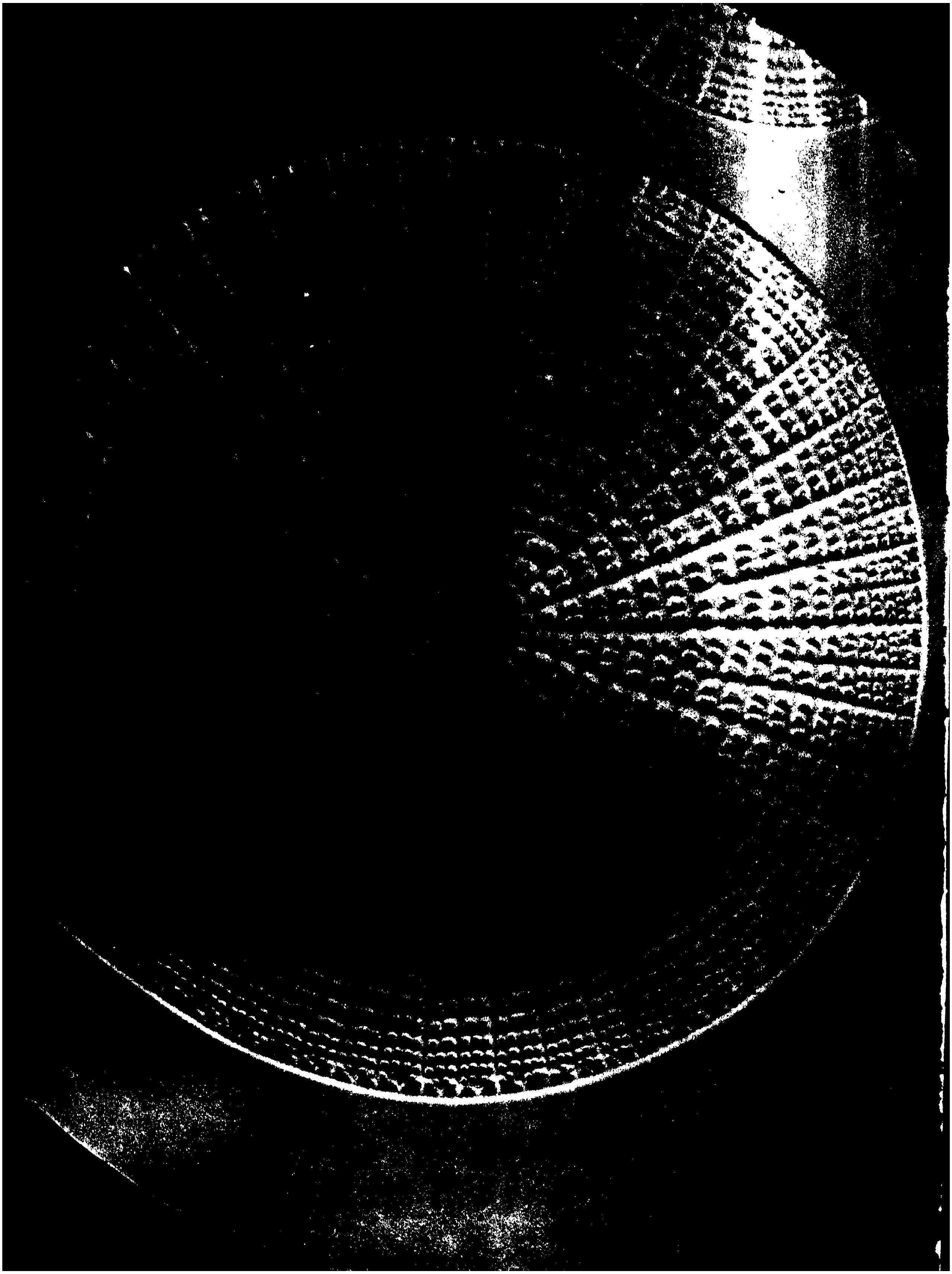


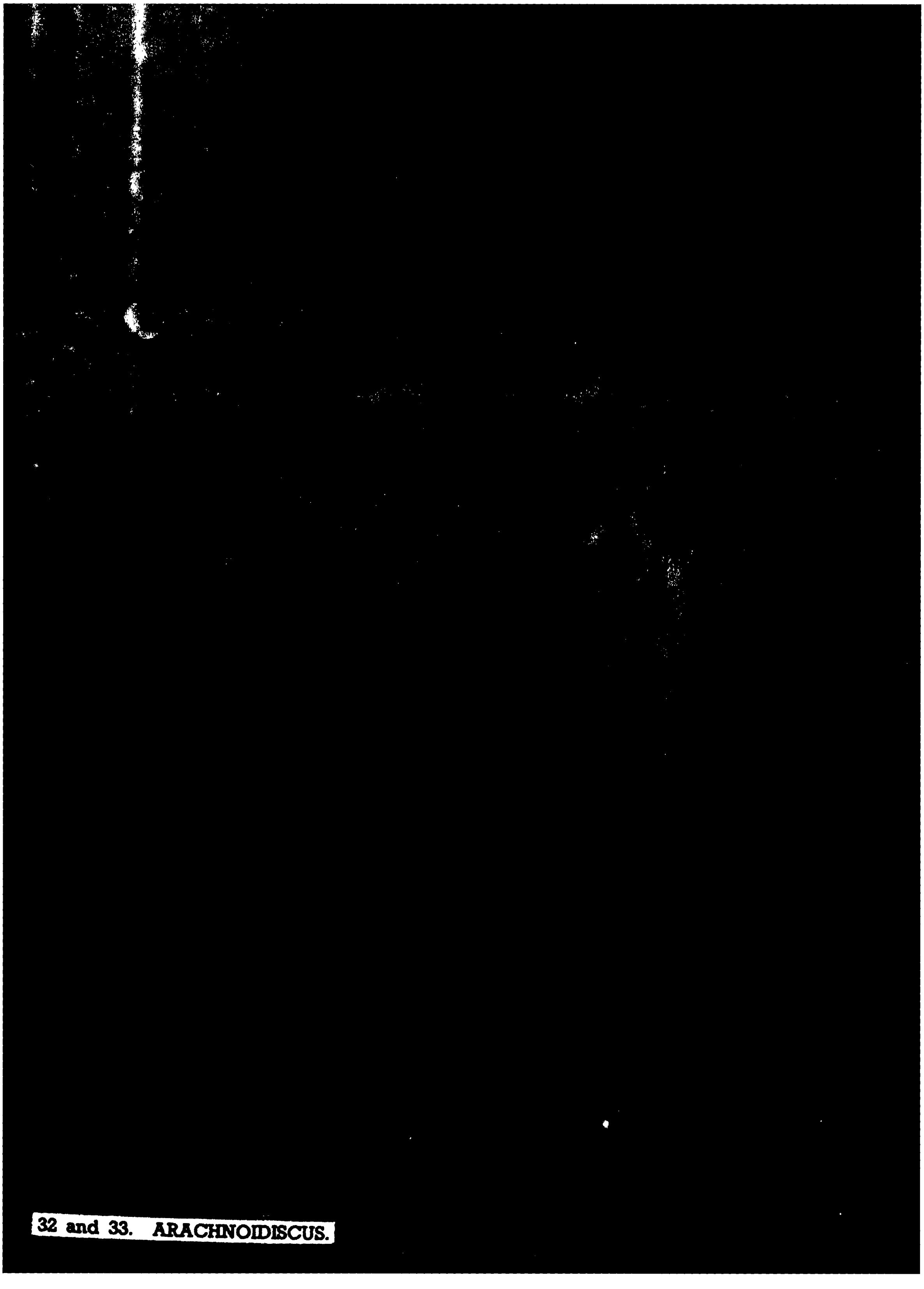
30. FRESHWATER ALGÆ (Bactrocho Spermum).
More slime—but when in a small cell under the microscope it revives, and reveals itself as a delightfully fronded plant waving in invisible currents, and of vivid colour.

## 31. SPINE OF ECHINUS.

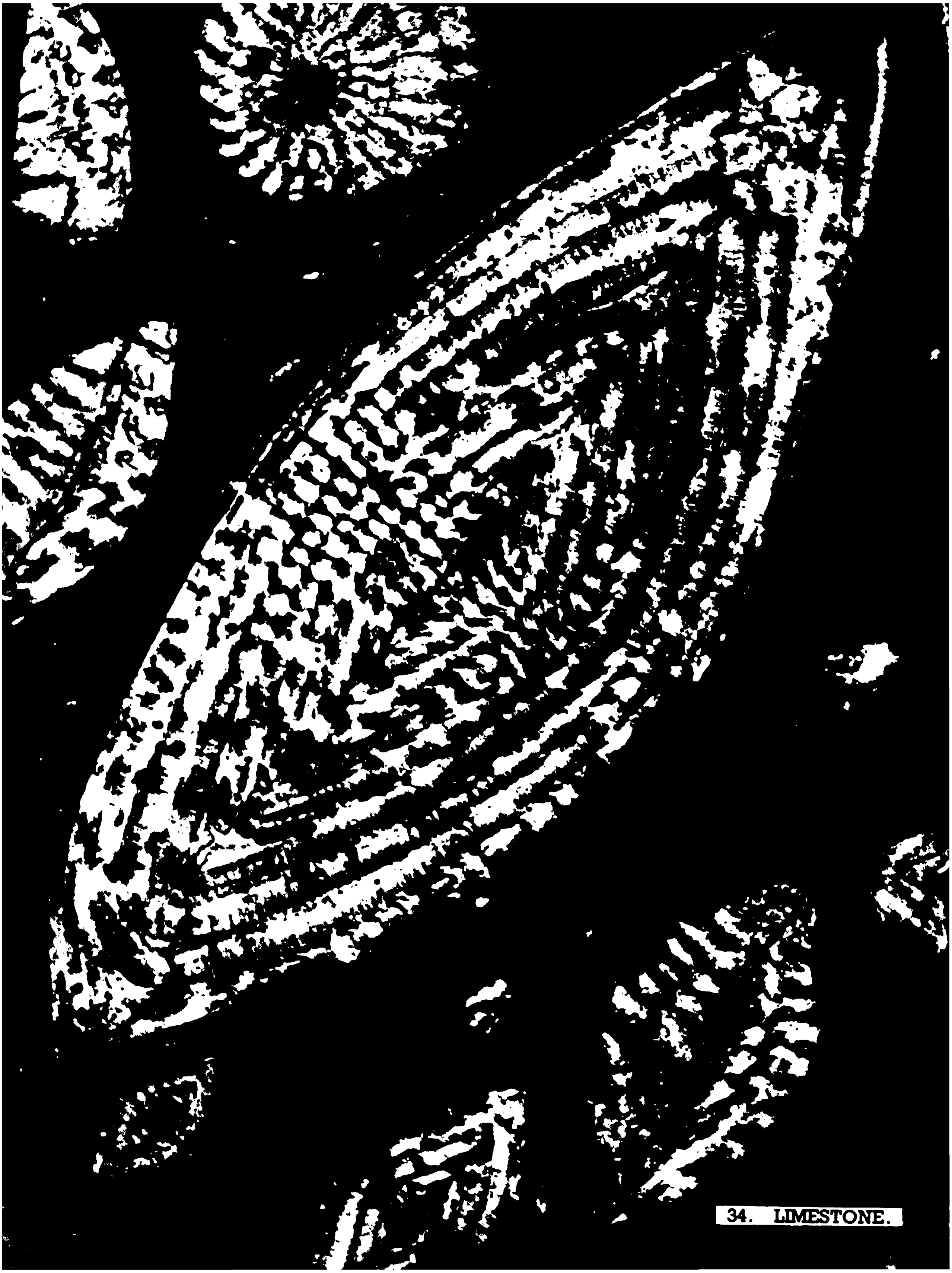
Each different specimen of the Echinus family will be found to have a different arrangement in the structure of its spines. The illustration below is from another type of the sea-urchin to be found on English shores.







32 and 33. ARACHNOIDISCUS.

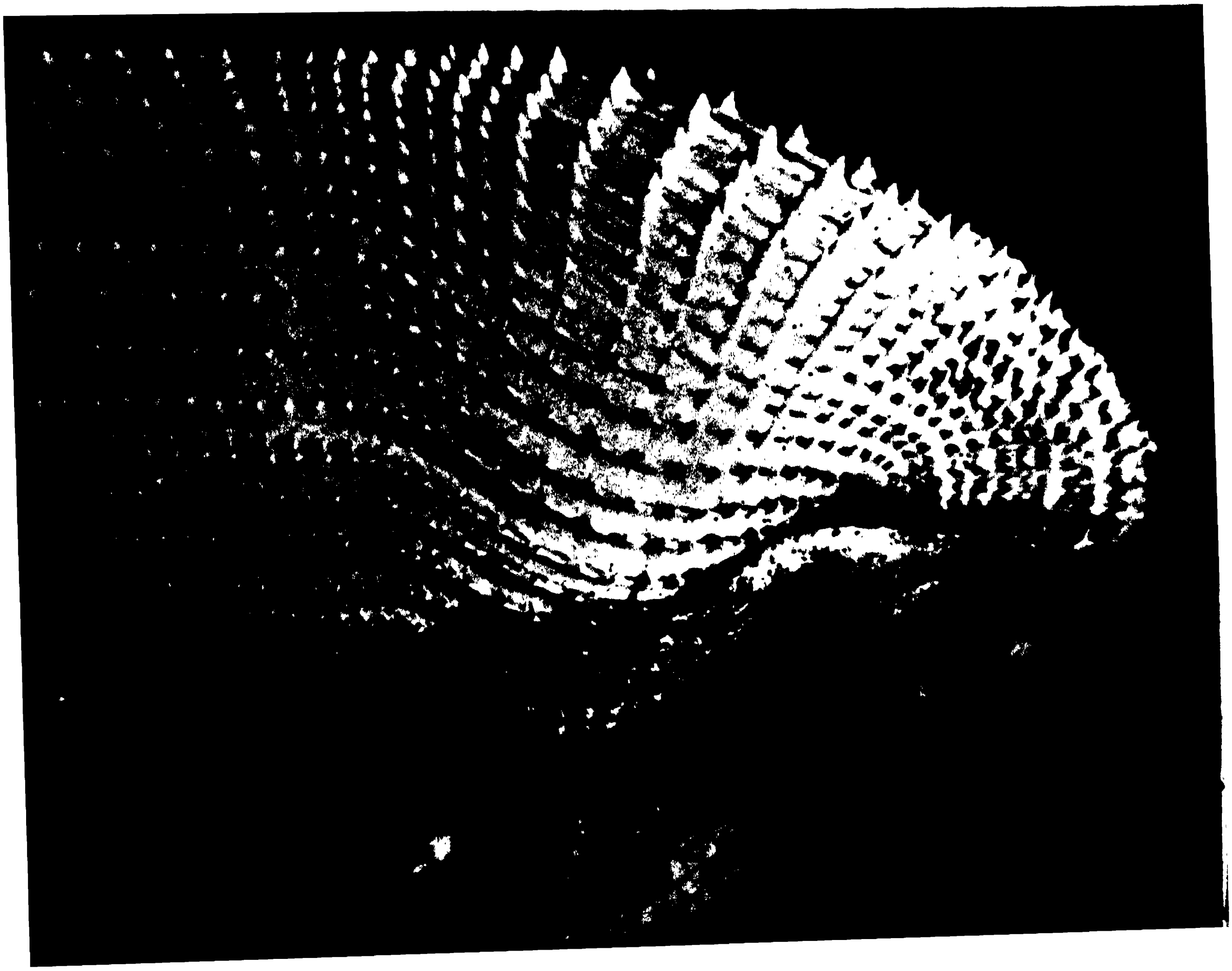


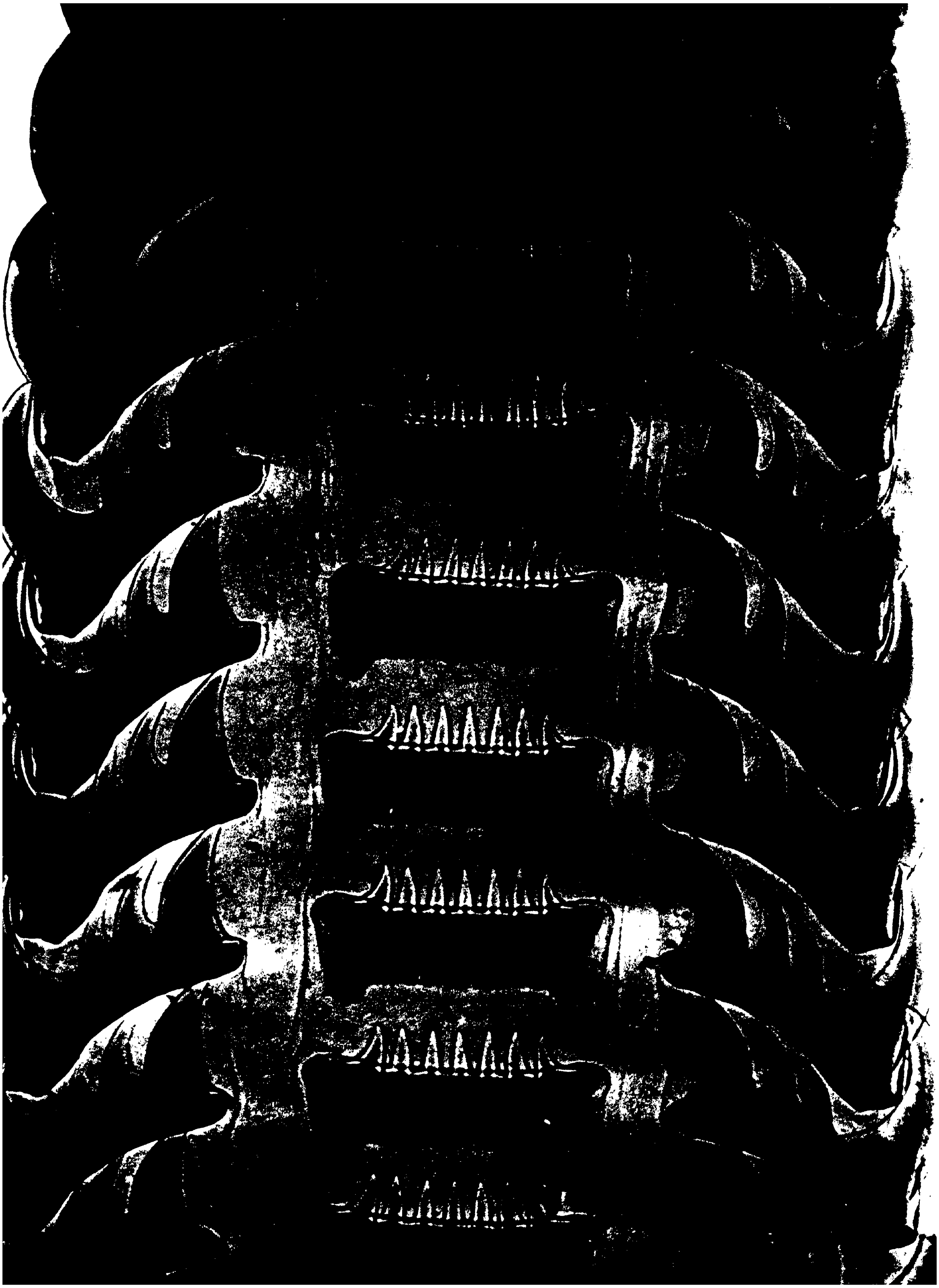
34. LIMESTONE.

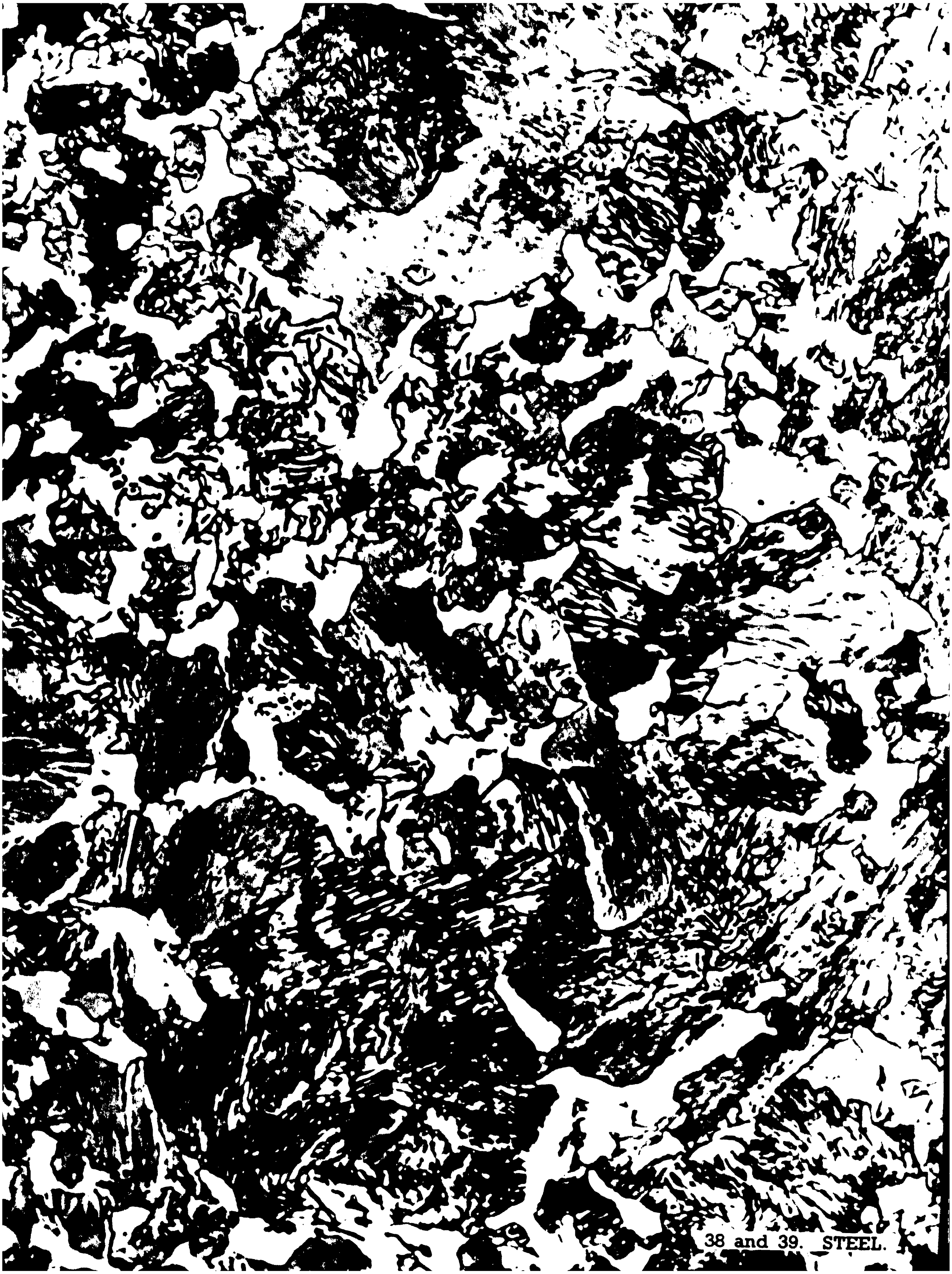
35. HUMAN BONE.

**36. Part of the shell of a PHOLAS, a marine mollusc that bores holes in limestone rocks.**

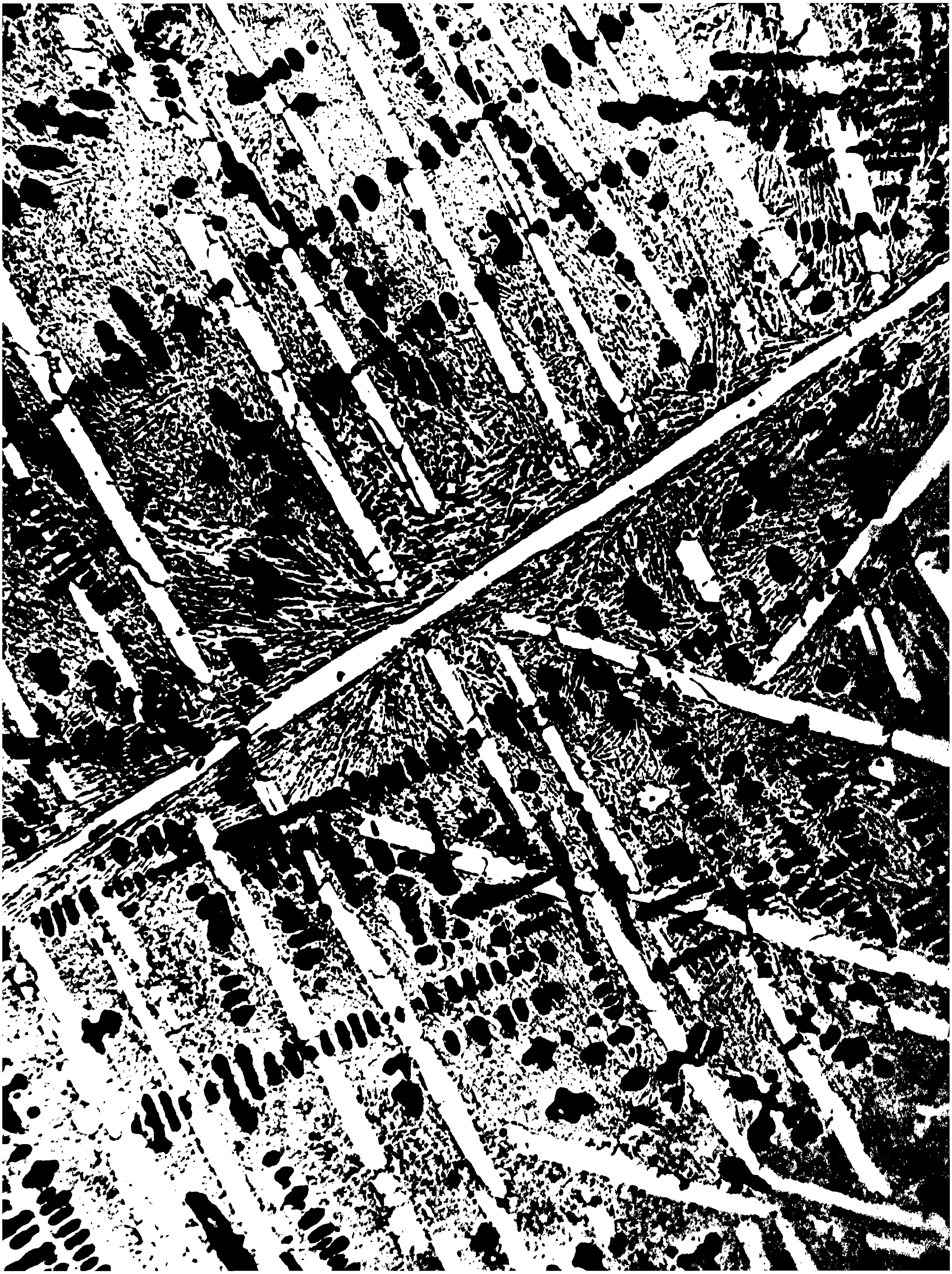
**37. PALATE OF A TONGUELESS SNAIL**—opposite.
**An example of another recent invention already discovered by nature. The teeth (and snails have from five to eight thousand according to their type) will be seen, and it should be noticed that the side teeth point in one direction, the central teeth in another. The centre part of this wonderful structure is like an endless moving band (or a tube escalator). Food is impaled on the central teeth and torn against the side teeth ; thus shredded it is ready for digestion.**



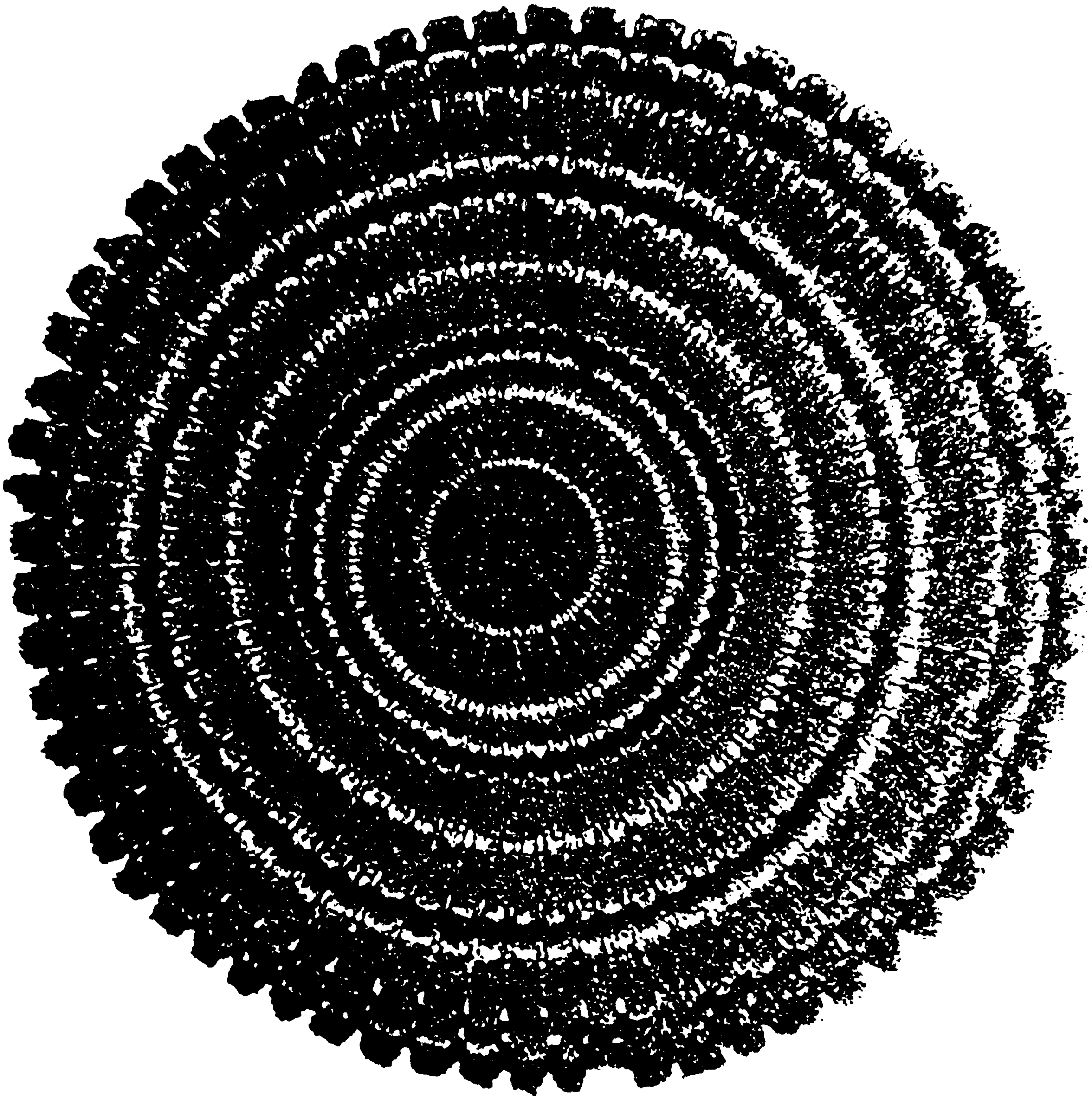


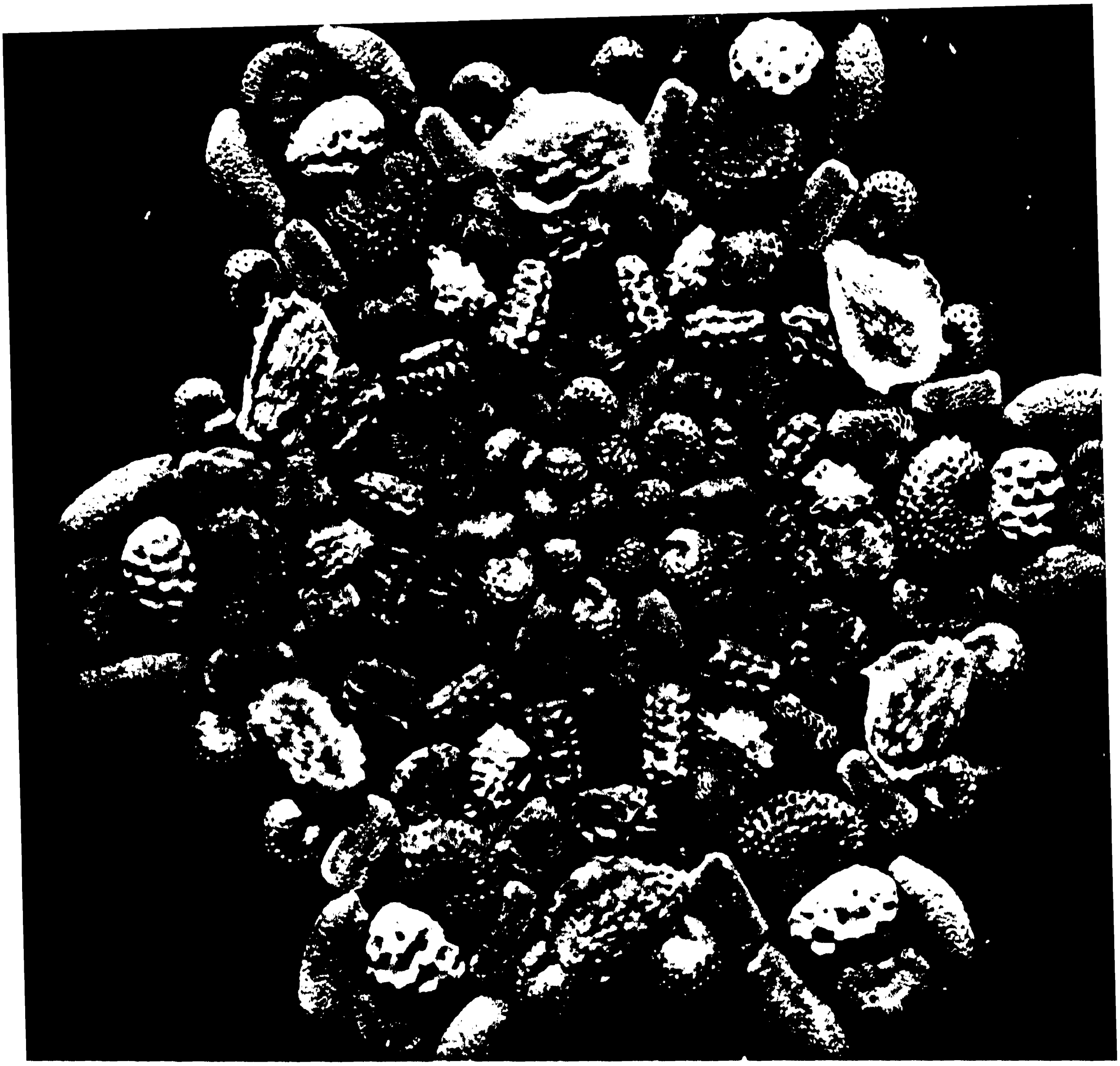


38 and 39. STEEL.



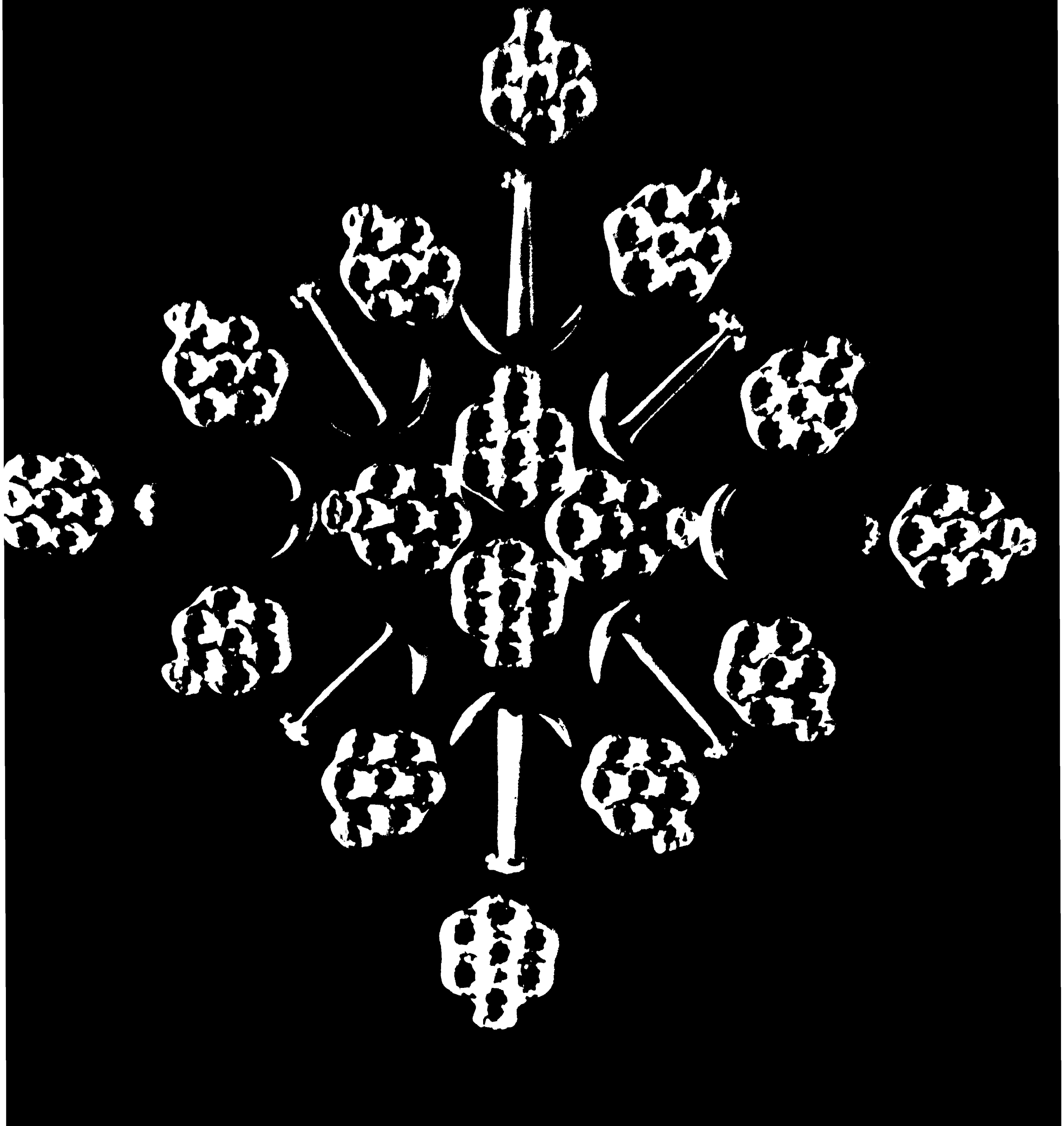
40. SPINE OF ECHINUS. Yet another variant of the sea-urchins spine.



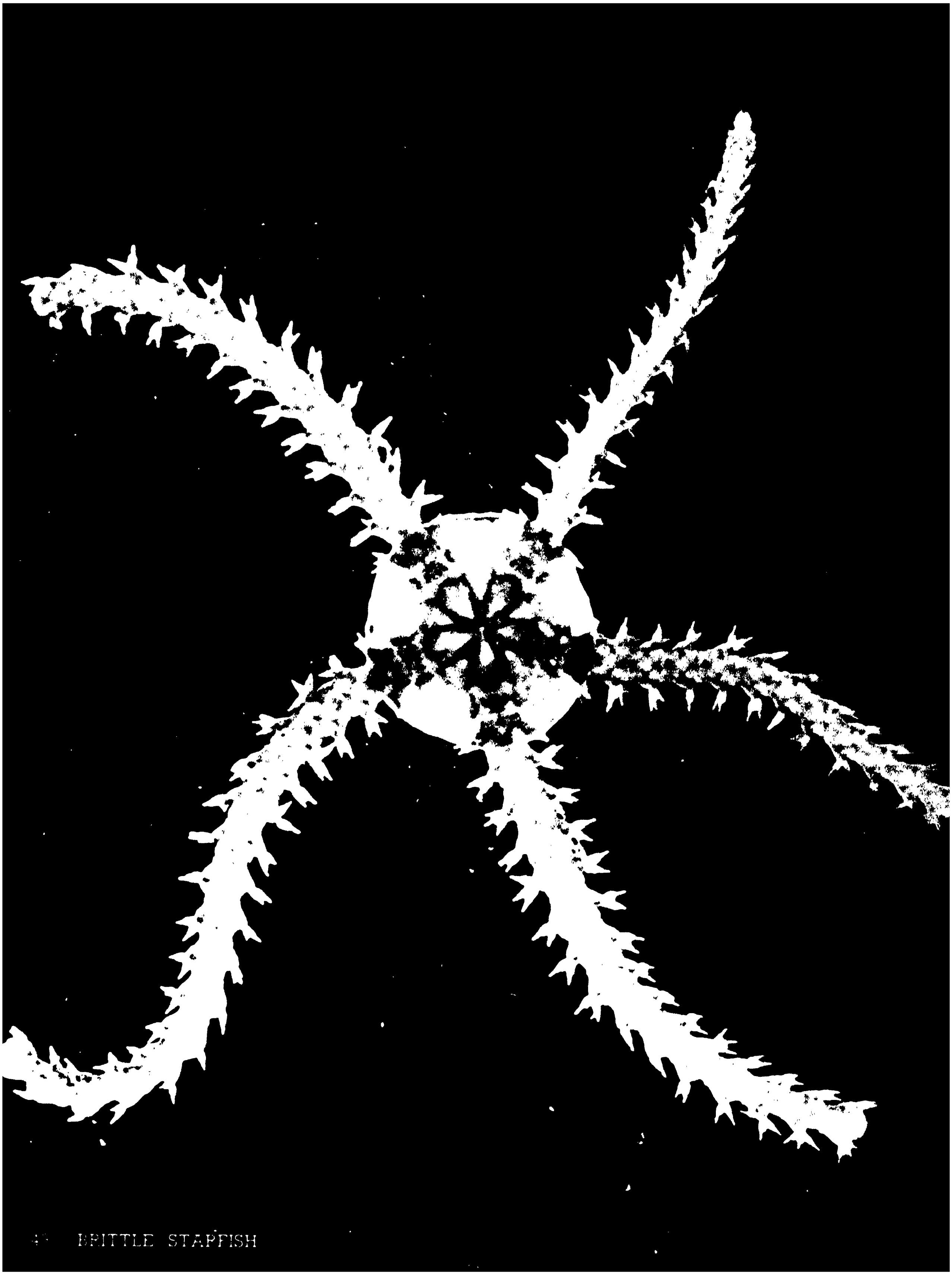


41. FLOWER-SEEDS.

The microscope reveals nature's ability to ensure the survival of the species. Some flower-seeds are provided with wing appendages that they may be carried by breezes, others with short spikes to ensure a grip on the ground where they fall, while others are reinforced to withstand being blown about by the wind. Some of these different types may be seen here.



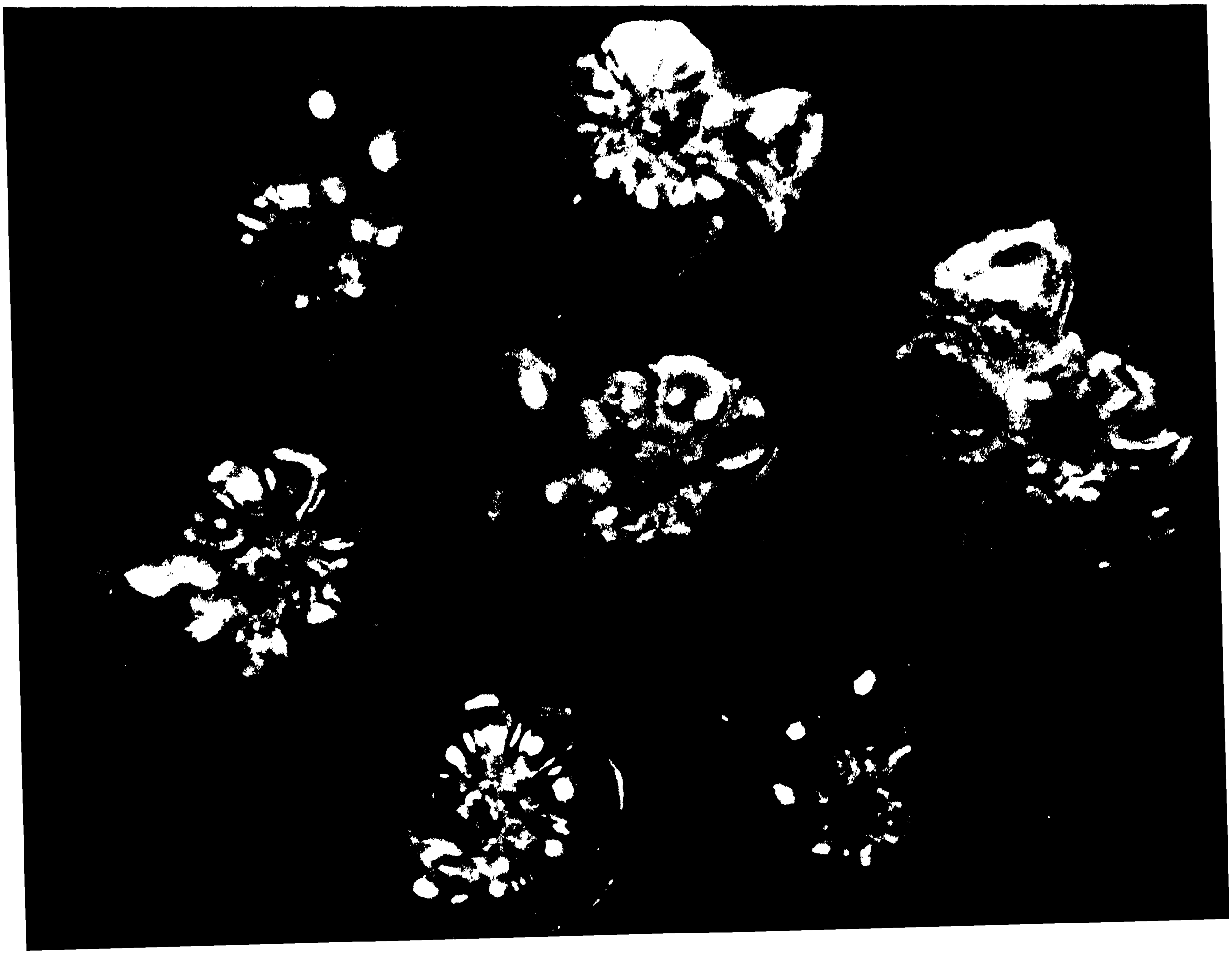
47 PLATES AND ANCHORS OF SYNAPTA

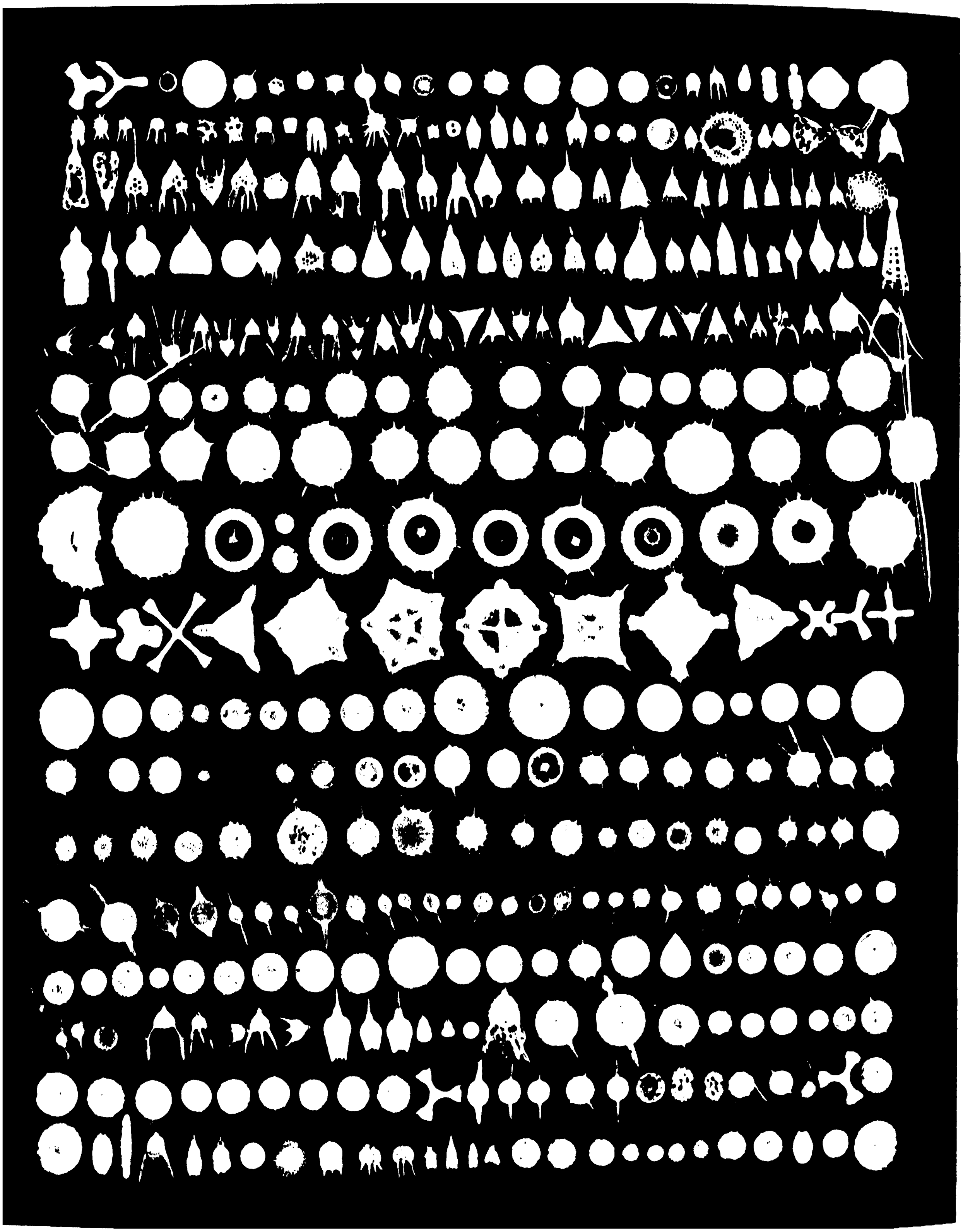


4[illegible] BRITTLE STARFISH

**44. LICMOPHORA (Marine Diatom)**—opposite. **The actual growing condition of this diatom is here seen, the graceful fan-like structure making for strength.**

**45. FORAMINIFERA.**

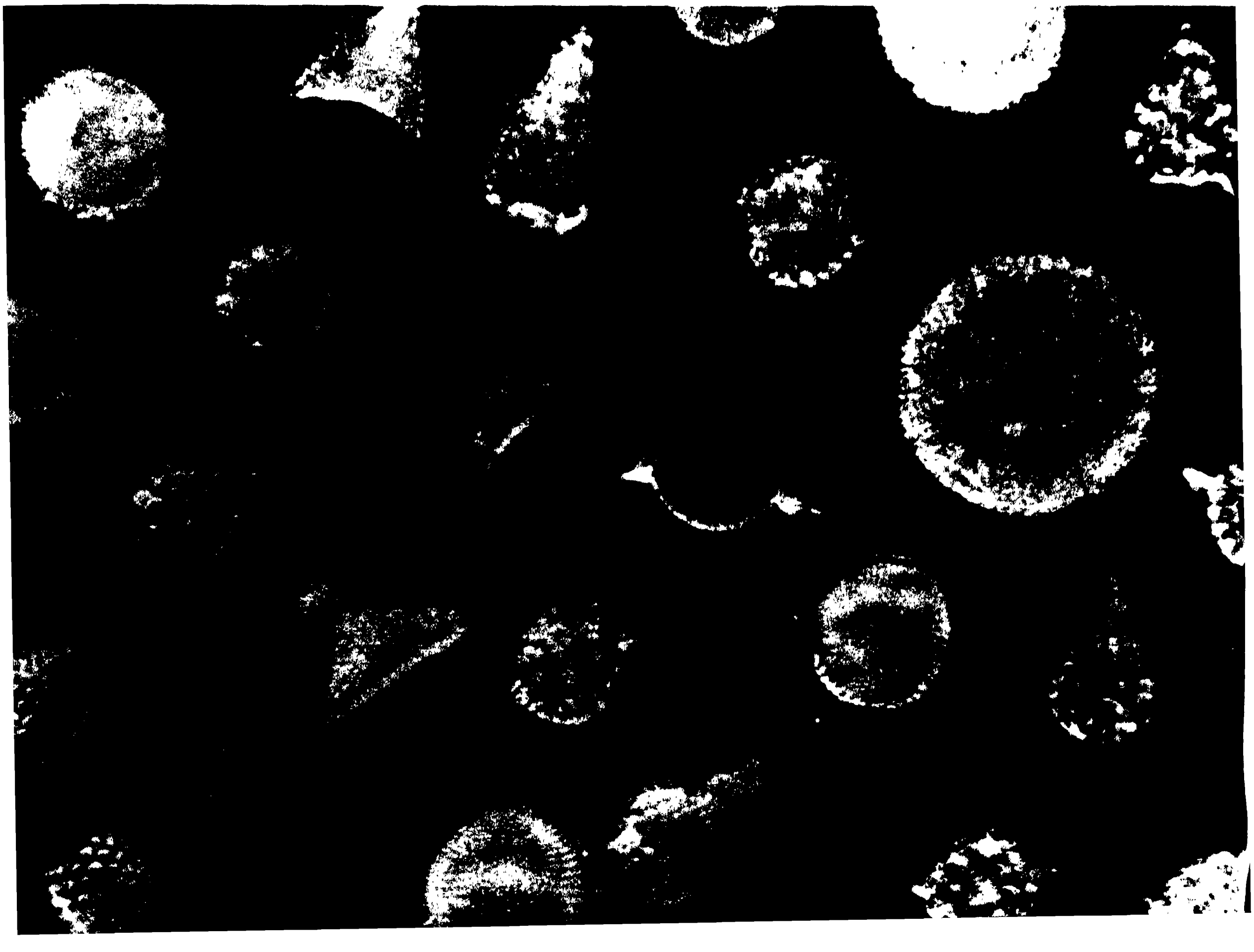




POLYCISTINA. The illustration is a type slide, showing some of the many patterns of these shells.

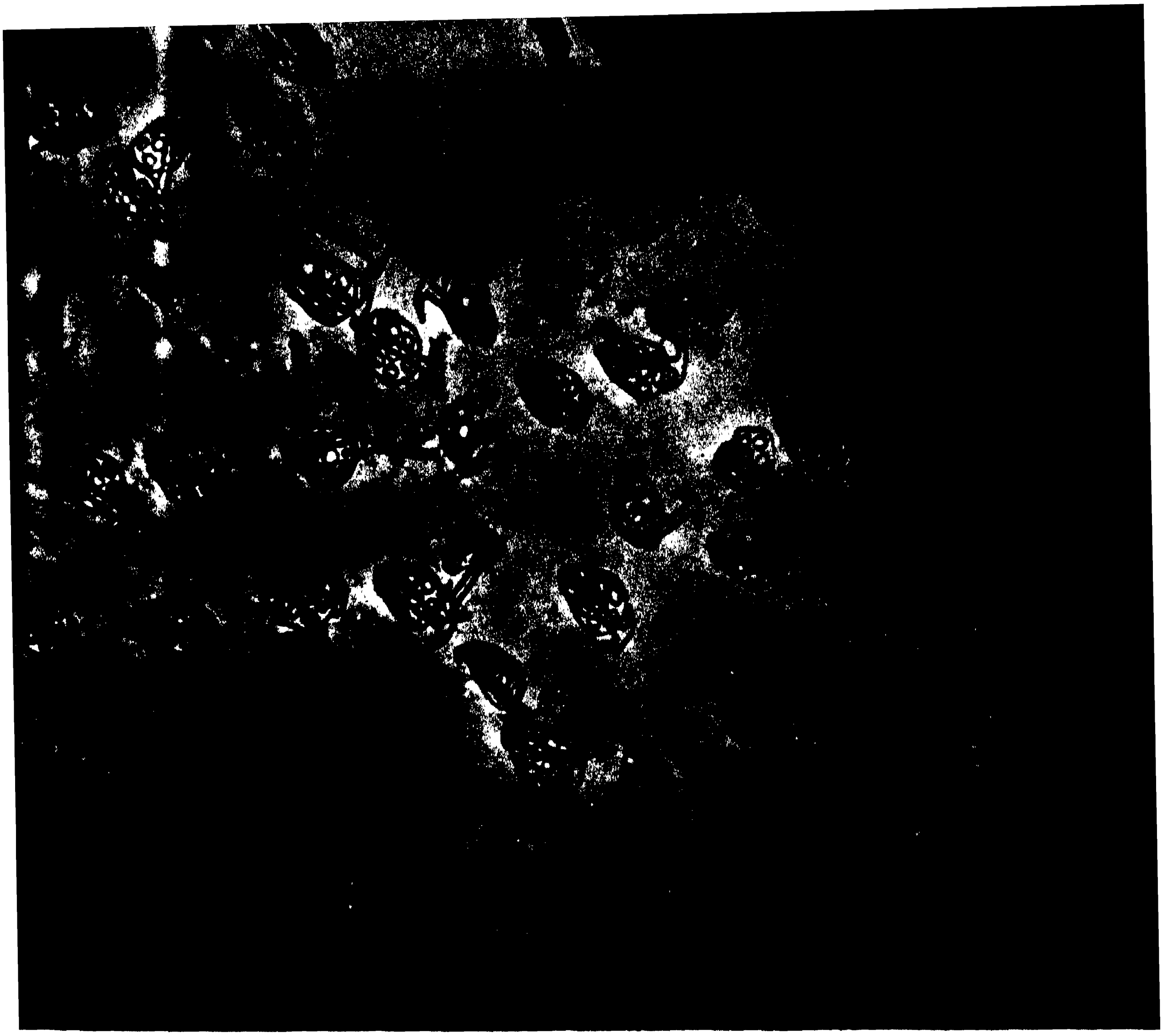
47. RADIOLARIA.

Under higher magnification these appear even more beautiful than many Chinese carvings.

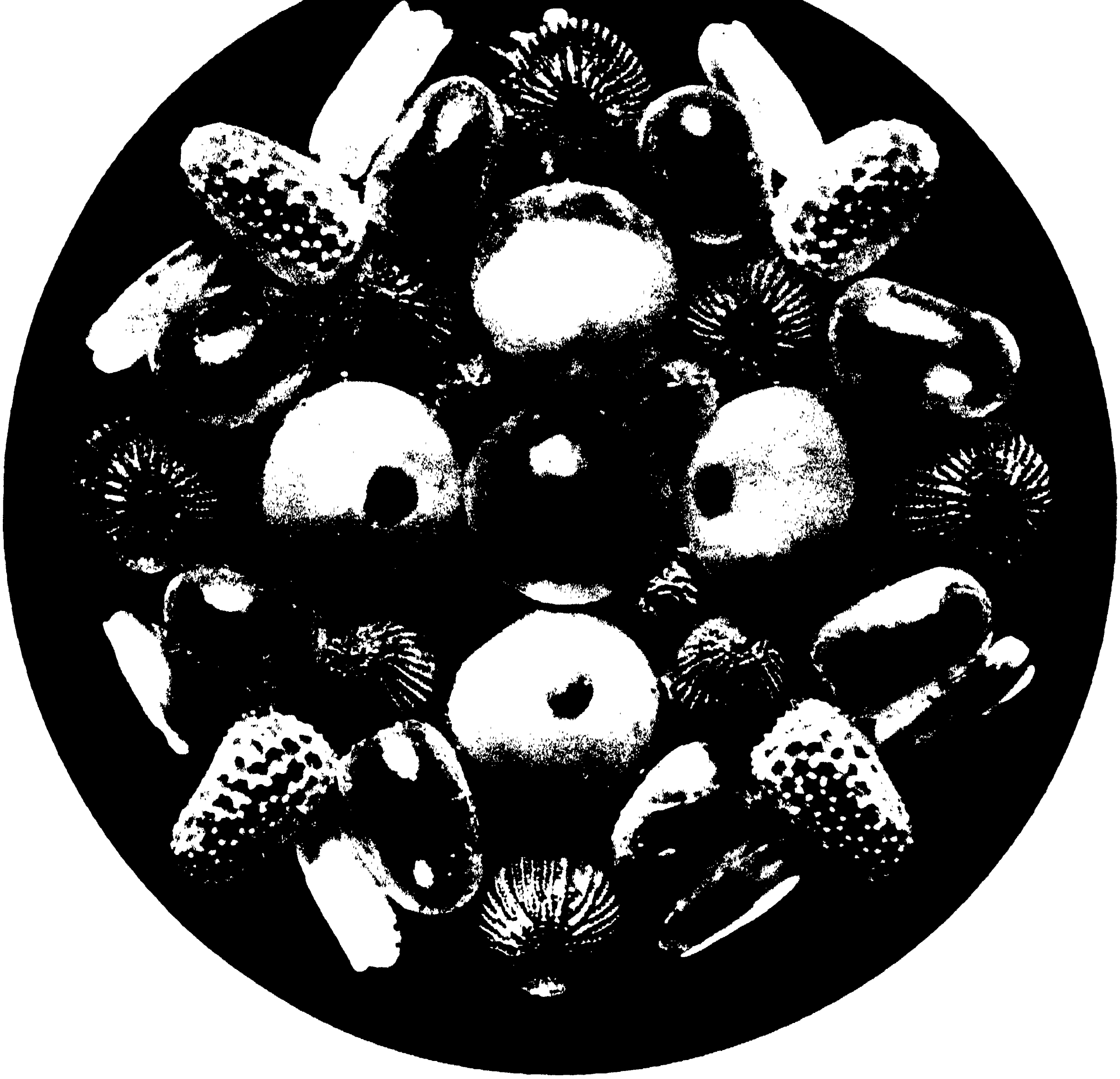


*48. AMŒBA.*

The lowest and simplest form of life. As a tiny mass of jelly it sprawls along, changing form with each passing month. On encountering a likely morsel of food it flows around, over and under its meal, ingesting it into itself.



49. ANCHORS AND PLATES OF SYNAPTA. This curious armature, embedded in the skin of the soft-bodied Synapta, takes the place of the bony skeleton in the higher forms of life, and keeps the creature distended.



50. A GROUP OF INSECT EGGS.
Minute as these eggs are, each one has to be blown before mounting as a permanent specimen. The eggs of butterflies, moths and some flies and parasites are of surpassing beauty, both sculpturally and in colour. The "skin" of a pearl, the fire of an opal, carving exact and delicate, are to be found among them.

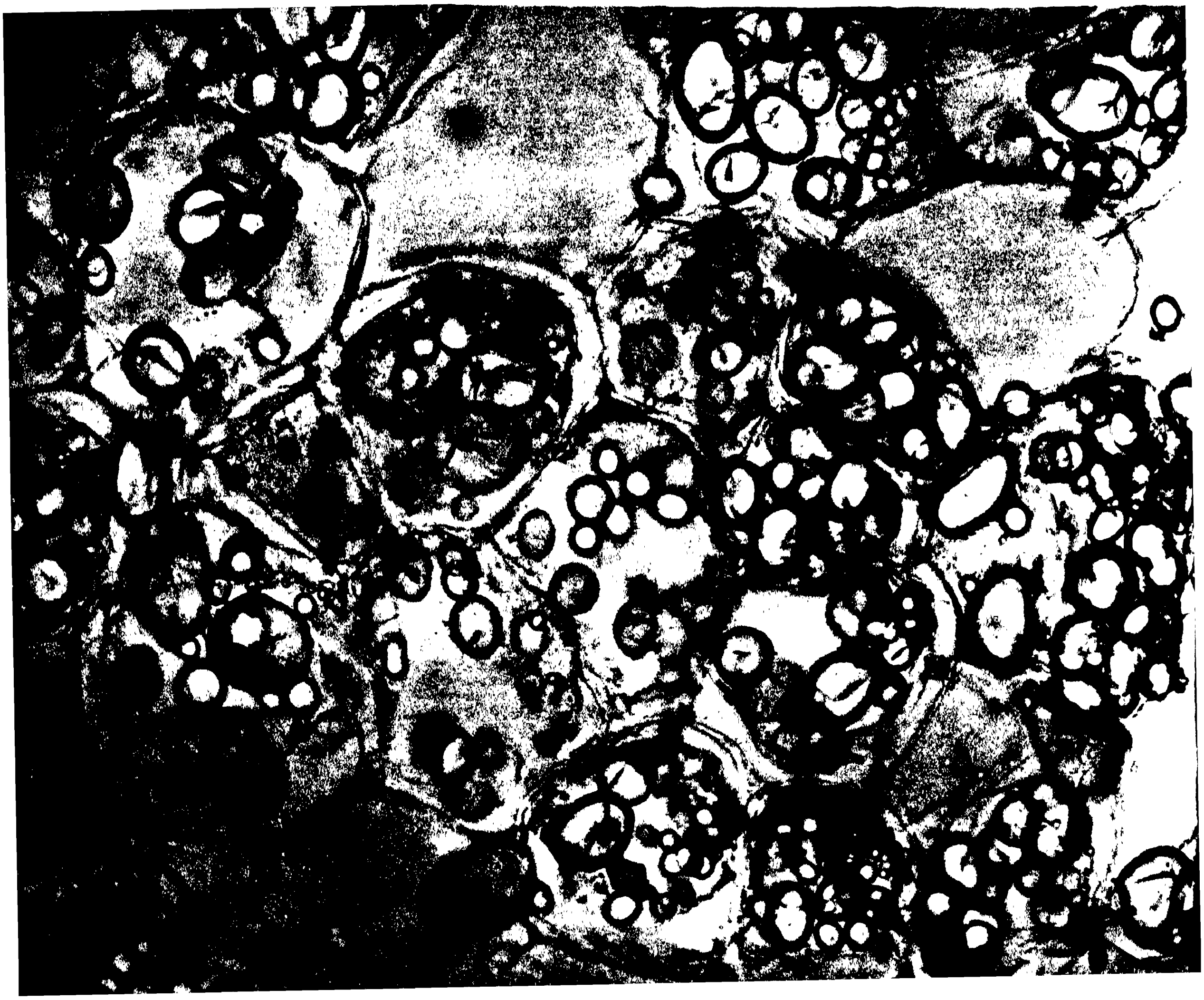
*51. GLOBIGERINA FROM THE FLOOR OF THE ATLANTIC*—opposite.
These belong to the family of the Foraminifera, and vary largely according to locality, being influenced by temperature, food, pressure from depth of water, etc. The design of the shells will be noticed and the manner in which, despite their minute size, the various artifices used by engineers to resist strain are present.

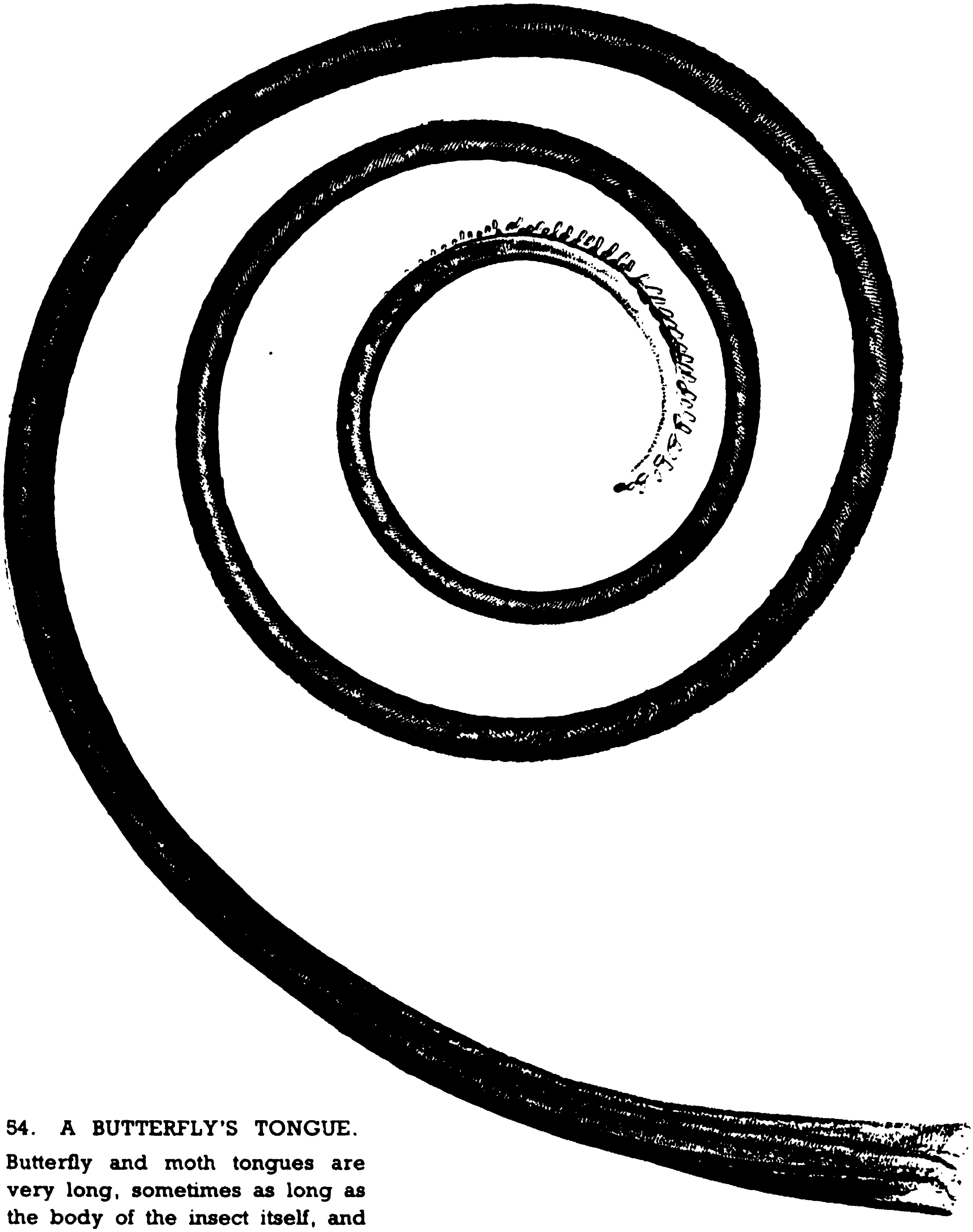
## 52. POTATO CELLS SHOWING STARCH.

Starch is a prominent constituent of potato, and the pearly grains will be clearly seen. There are many forms of starch, yet by polarised light all can be unerringly differentiated in spite of their similarity of appearance.

## 53. ASPERGILLUS GLAUCUS—opposite.

Mould from cheese, in other words. Apart from the beauty of the specimen itself note the filamentous structure which penetrates the cheese and the spore formations. Each spore is capable of giving rise to a fresh fungoid growth.



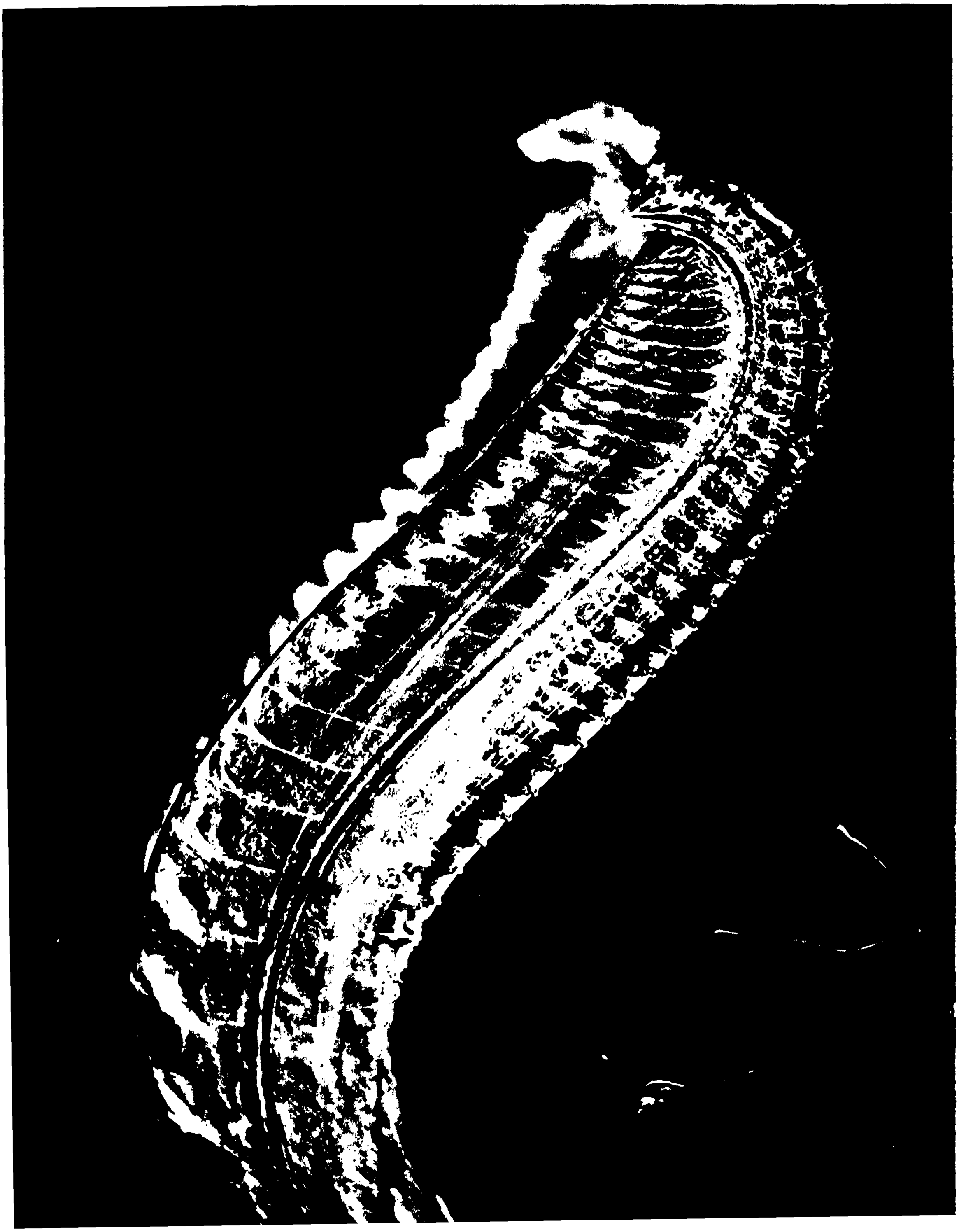


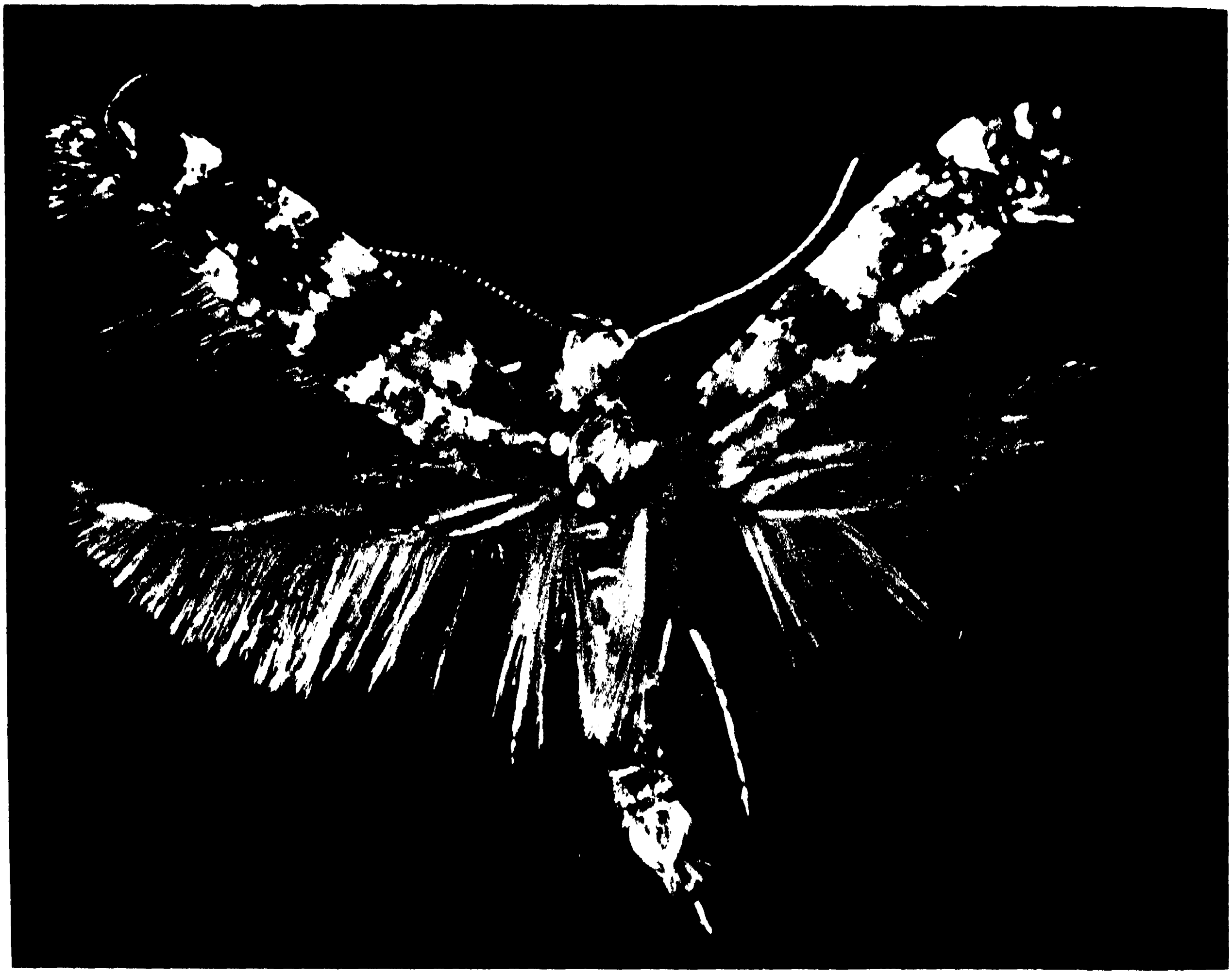
54. A BUTTERFLY'S TONGUE.

Butterfly and moth tongues are very long, sometimes as long as the body of the insect itself, and are used for delving down into the bells of flowers, to collect pollen. The bodies on the tapered end are taste buds.

55. THE SAWS OF A SAWFLY.

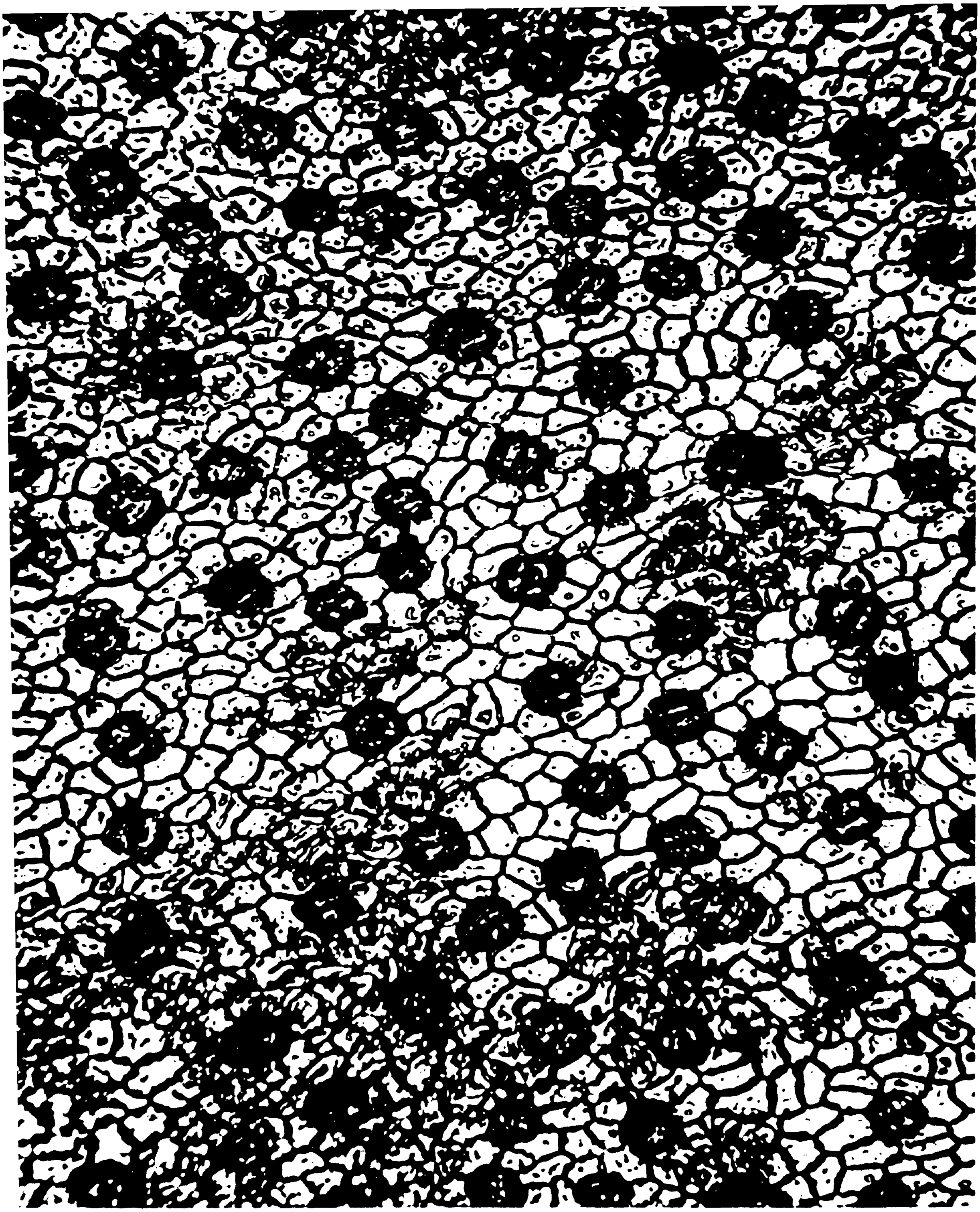
The sawfly lays its eggs in galls on leaves, and the saws are developed to enable the fly to split the gall ready for the ovipositor to penetrate. The eggs hatch just about the time that the larvæ of other insects already inside the gall have developed, providing food ready for the sawfly.





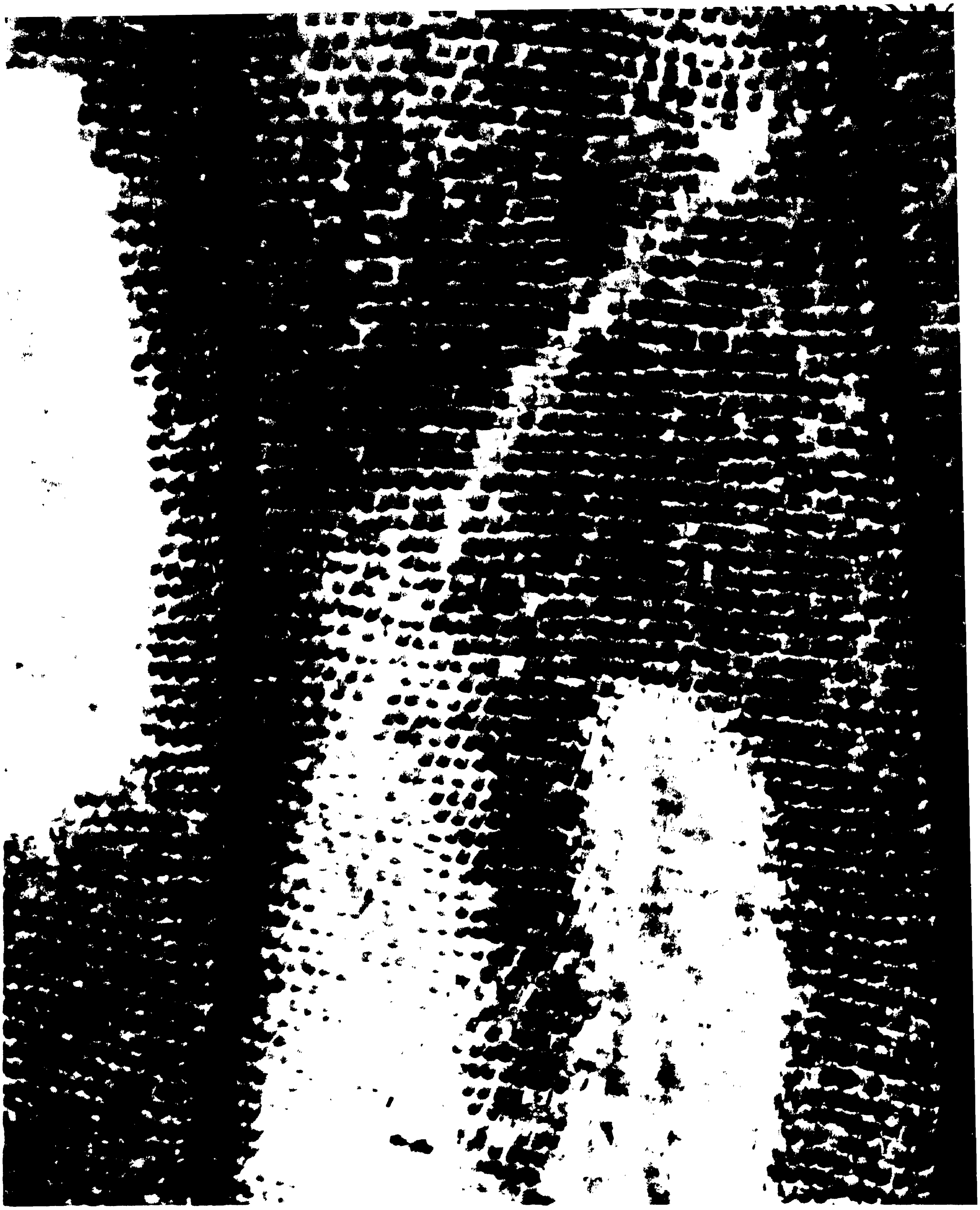
56. LILAC MOTH.
The beautifully arranged scales on the wings, and the jointed antennæ, are worth noticing. The hairs surrounding the wings and body make this minute moth—which does not measure more than half an inch from wing tip to wing tip—one of great beauty to the observant eye.

57. SCALES OF HAWK MOTH—opposite.
A type of the individual scales which cover the wings of butterflies and moths are shown here. Note the base which is attached to the wing skeleton, the fine tips and the vertical ribbing. The dust left upon the fingers after handling one of these insects is actually composed of such scales.

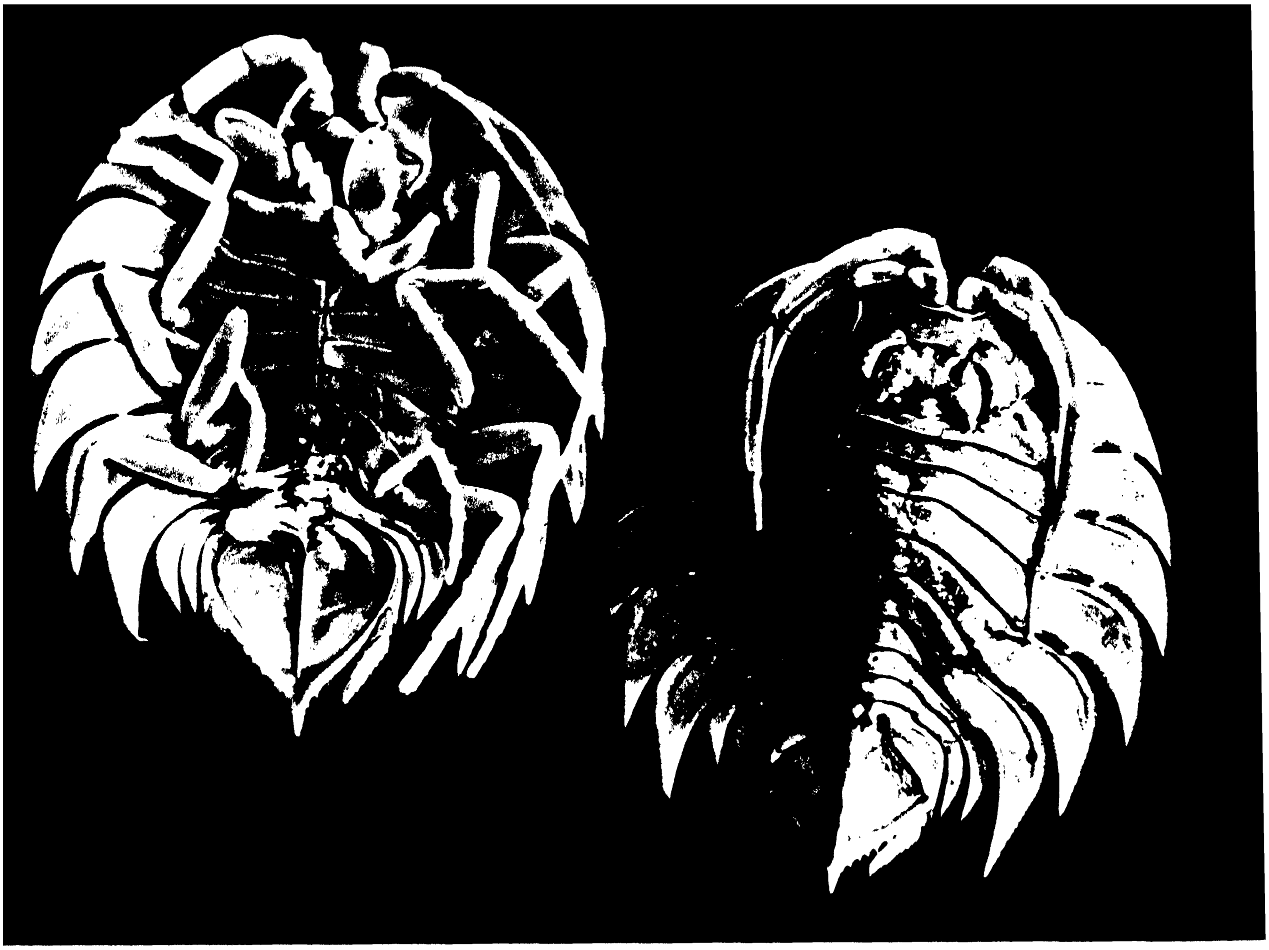


58. STOMATA OF BOX LEAF.

It is generally known that plants breathe through their leaves, and the pores are clearly shown in this illustration. The stomata are to be found in the fleshy part of the leaf which covers the skeleton.



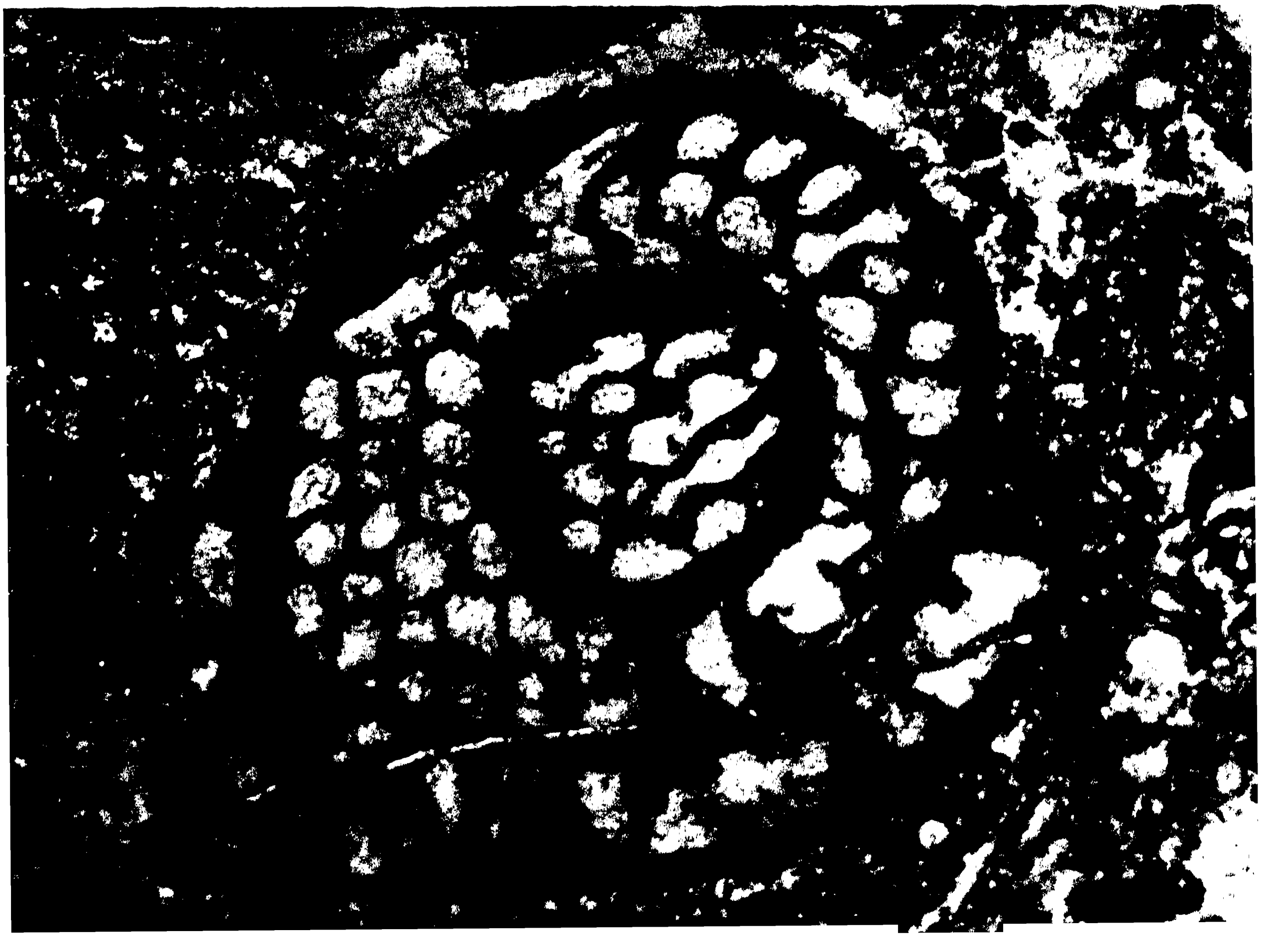
59. THE WING OF A BUTTERFLY.
The design of the wing skeleton, with the geometrically precise arrangement of the scales, can be clearly seen. The resultant grip of the insects wings upon the air will be easily appreciated.

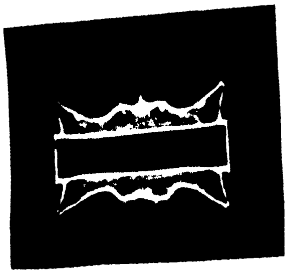
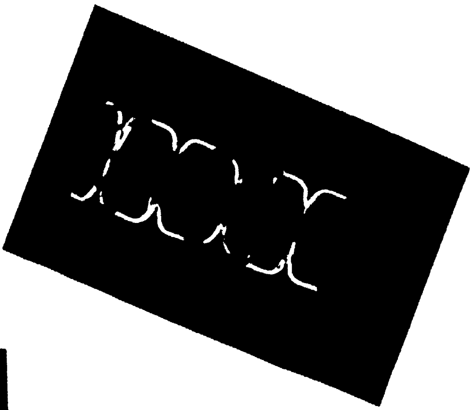
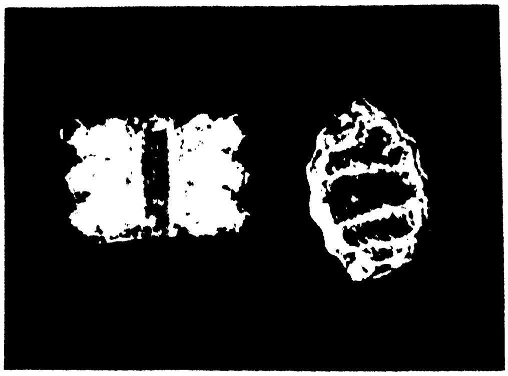
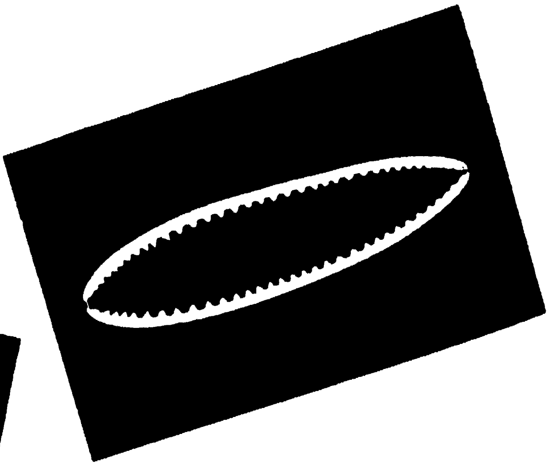
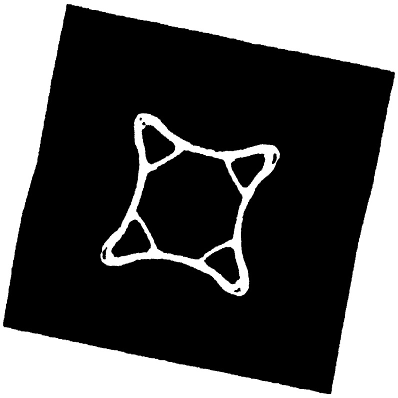
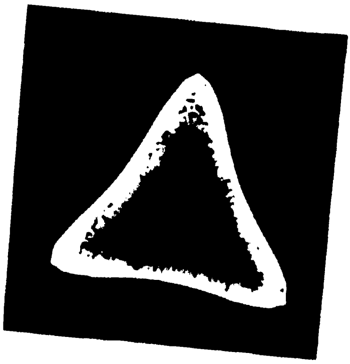
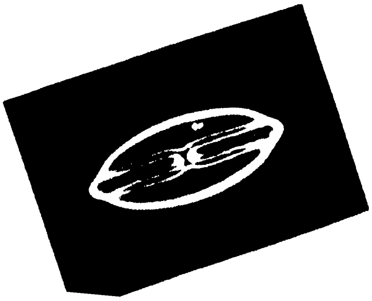


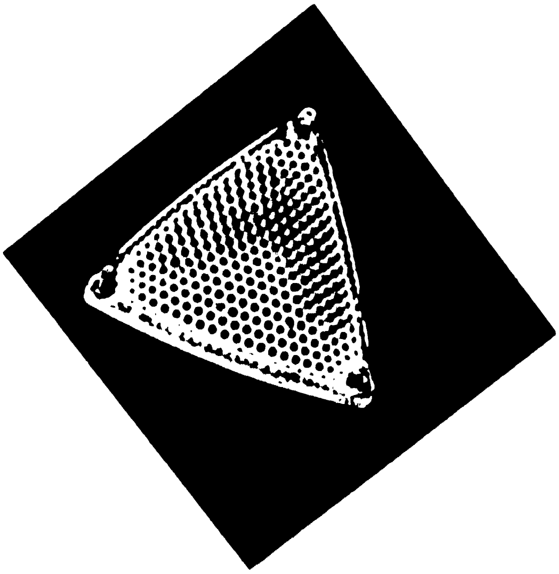
60. SERIOLIS (a marine isopod) UPPER AND UNDER SURFACE.

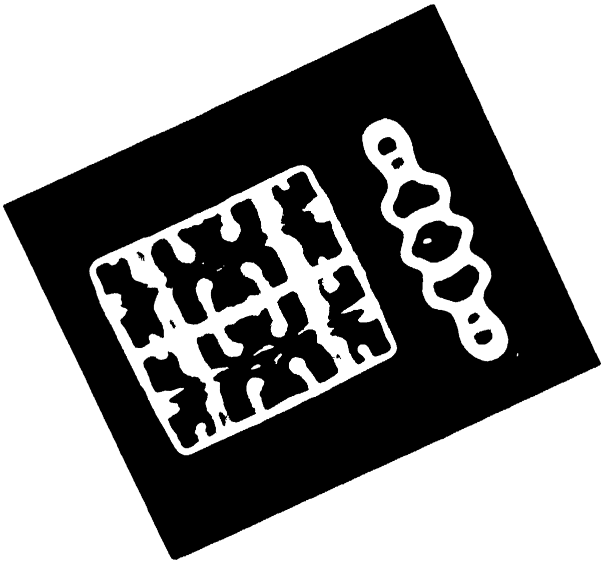
This animal is of interest, not only as a survival from much earlier ages, but also for the completeness of its shell, which ensures thorough protection and yet allows freedom of movement in every direction. Contrast its strength and freedom with the human idea embodied in the deep-water diver's suit.

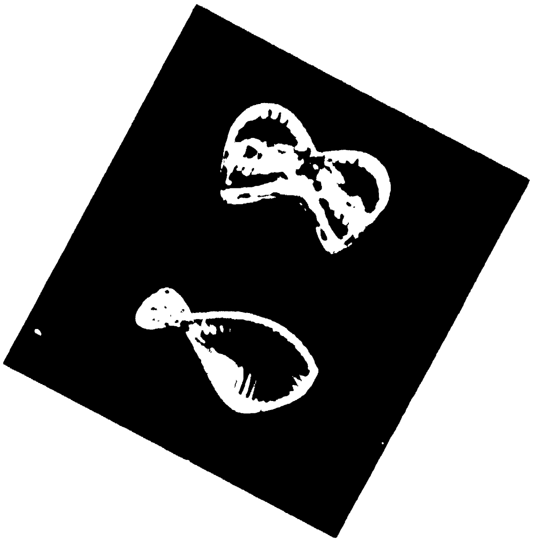
61. FUSILINA CHALK (fossil shell).
The greater part of chalk is composed of these fossil shell skeletons. To the geologist they tell the history of the growth of the world, and the architect and engineer can learn lessons from their mode of structure.



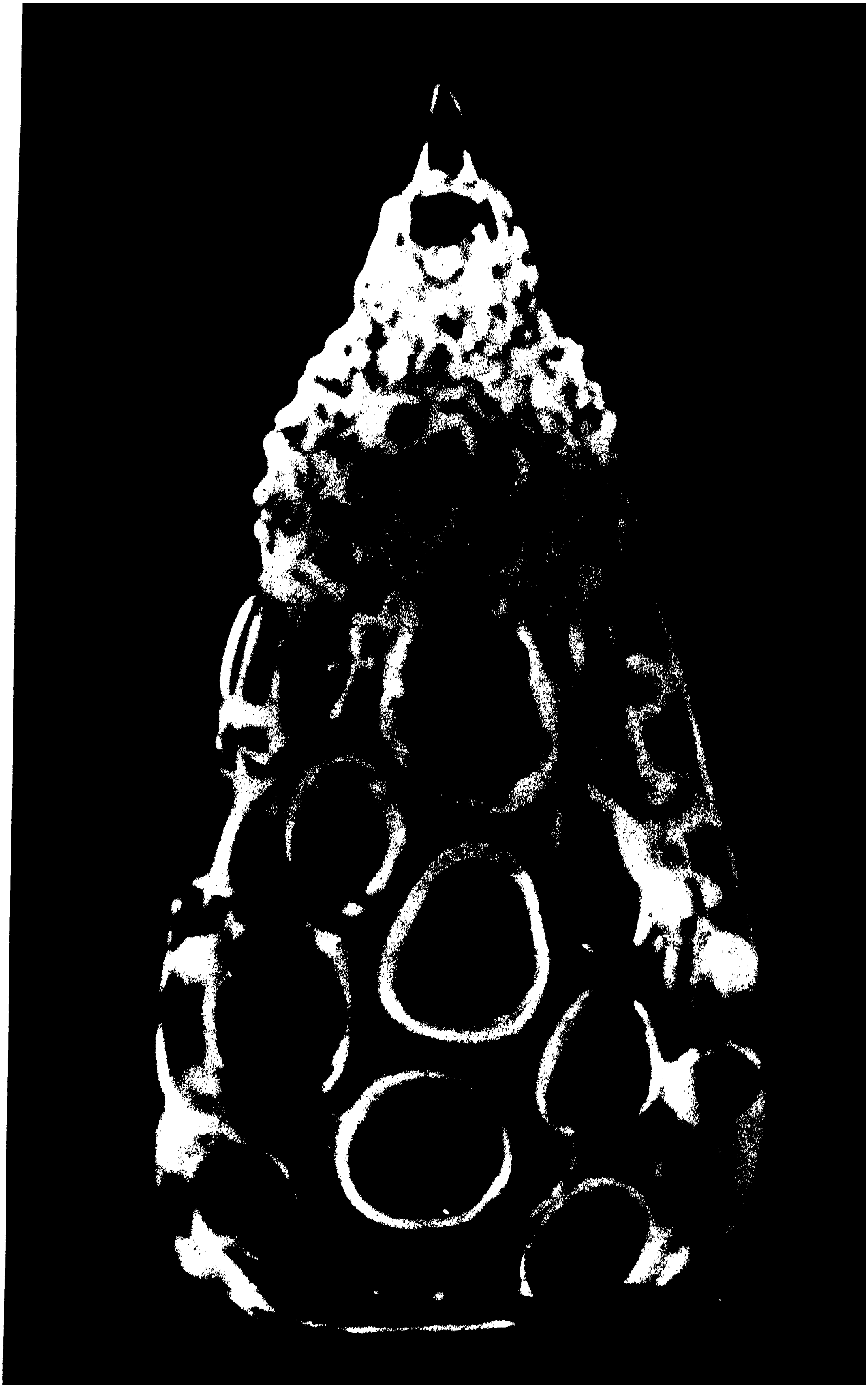


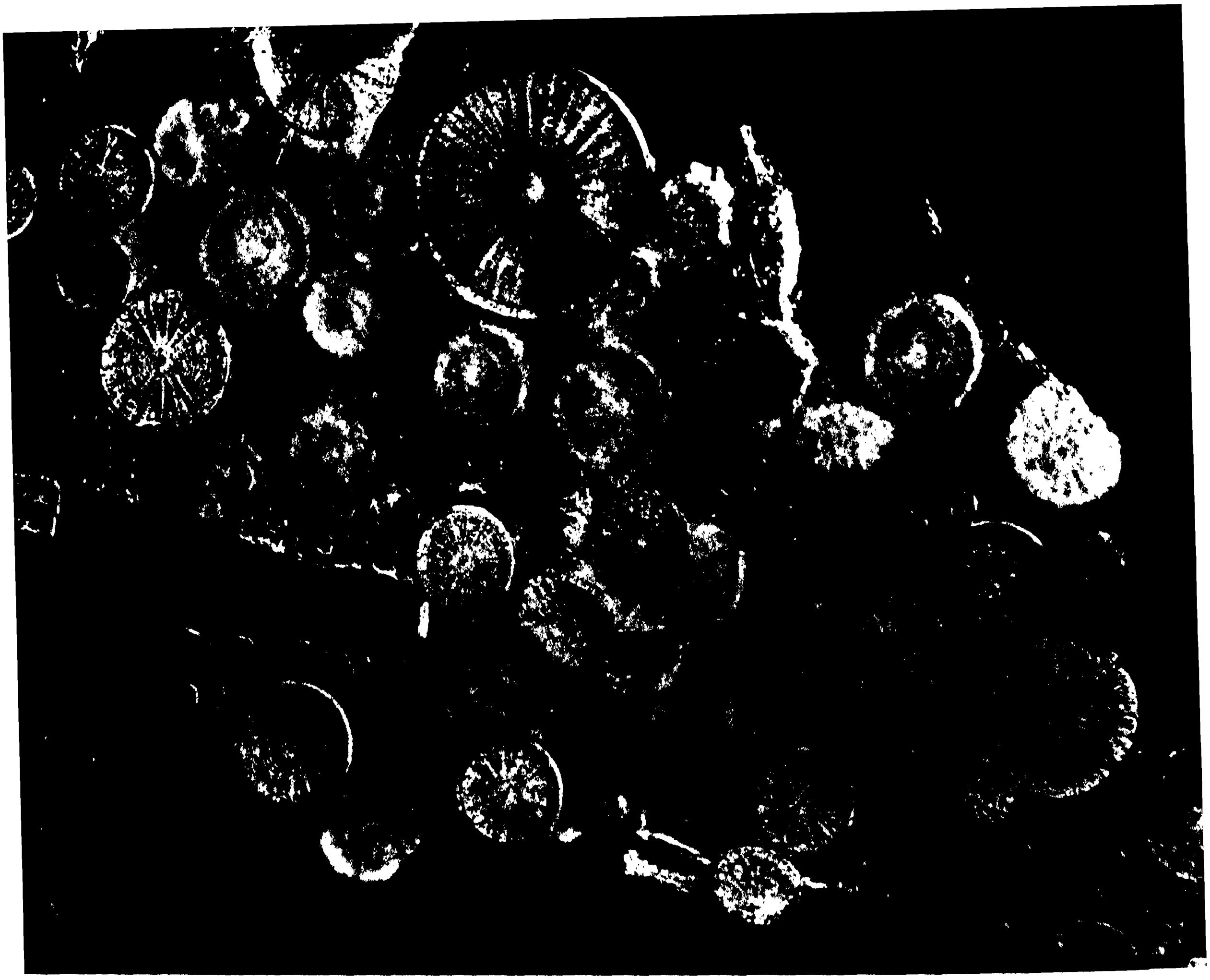




62 and 63. A GROUP OF DIATOMS.
These shells are constructed from silica by minute single-celled individuals, each smaller even than a pin's point, and there are over ten thousand known varieties of form. Nevertheless each creature builds only the shell of his particular species.

64 and 65.
RADIOLARIA.
In spite of the delicacy of hese minute shells (so small that a pinhead will accommodate wenty or more) hey are of great strength.

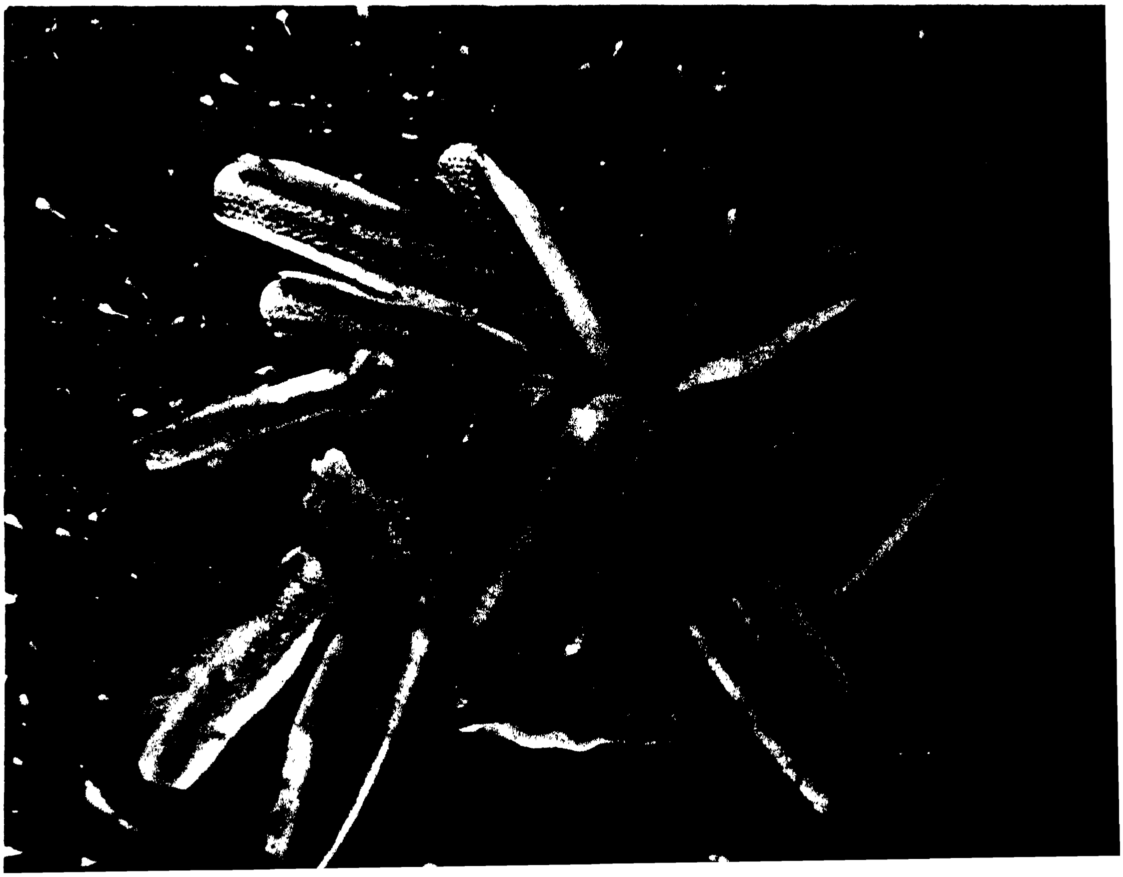




66. ARACHNOIDISCUS JAPONICUS. Another of the diatom family, a large group of flinty skeletons remarkable for the beauty of design, adaptability, and infinite variety of markings of its different species.

67. EGGS OF THE HOUSEFLY.

A very common object, but who would suspect its beauty of design, the horny comb structure and the ribbed edges sealing the egg chamber ?

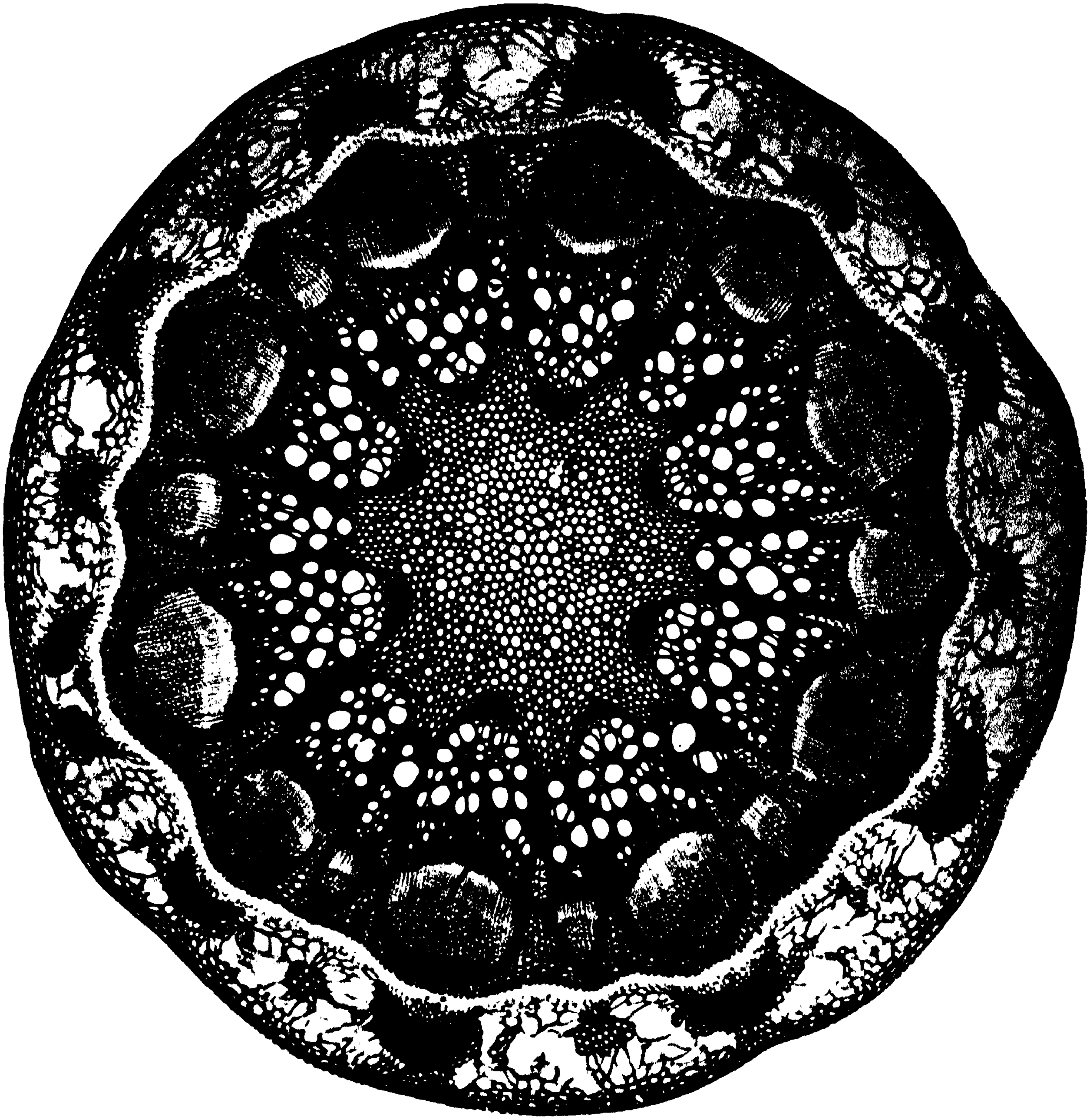


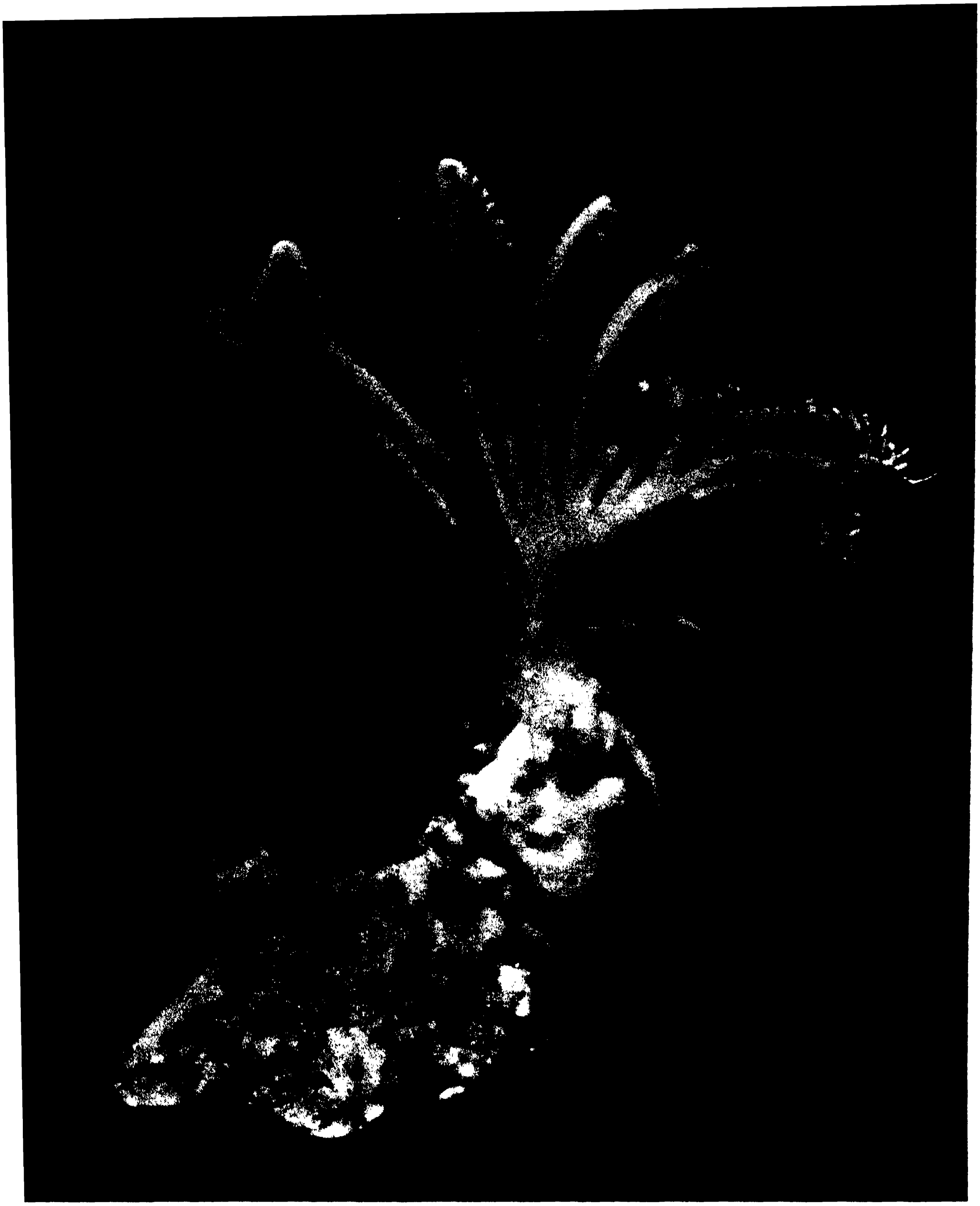
68. FELSPAR (From Cleveland Dyke).

The crystal of felspar occupying the centre of the field is typical in shape, and the twinning or growth of crystals at right angles can be clearly seen. Crystals grow as plants do, adding pieces from time to time, and in a perfectly symmetrical manner.

69. SECTION OF A CLEMATIS STEM.

Nature's provision of vertical strength to resist the elements is here displayed. The central structure of pith (corresponding with marrow in bones), the surrounding tissues with reinforced canals carrying nourishment, the woody structure, and finally the outer cork confining and strengthening the whole, show clearly.



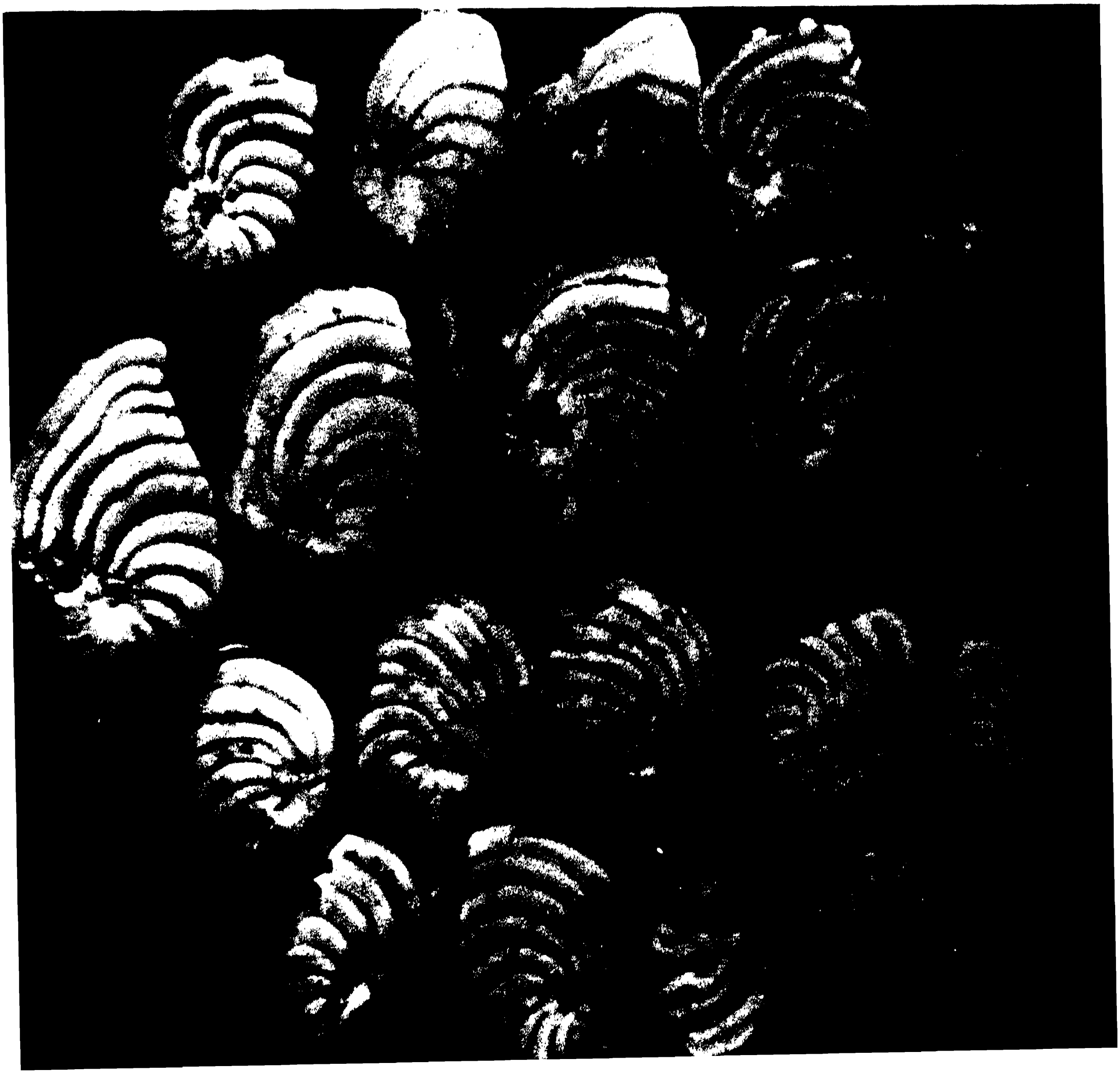


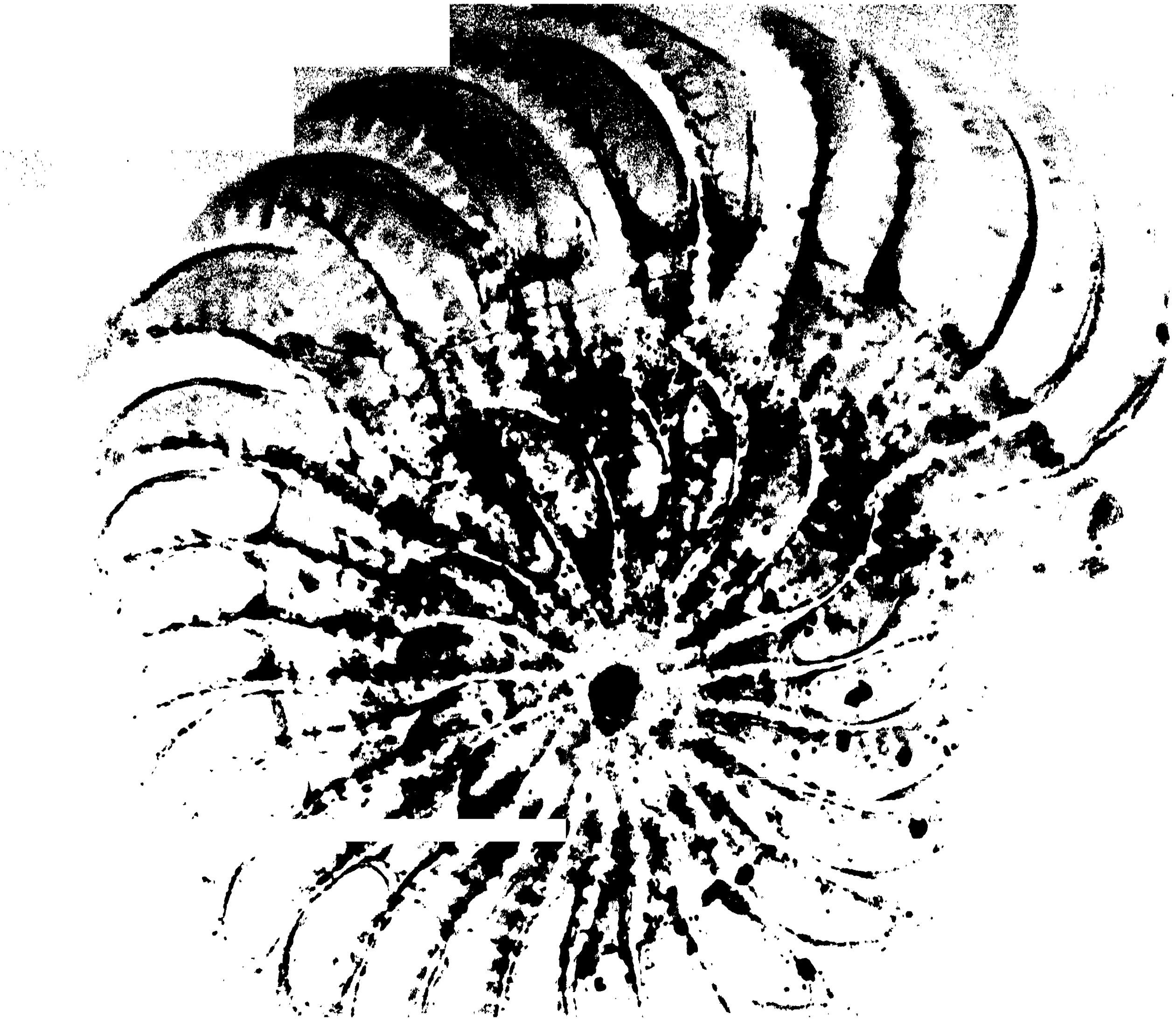
70. SERPULA (a marine worm).

A typical example of the many marine worms. Some burrow into the hard stone, others into wood, some build tubes of sand and cement them together. Having found their habitat they remain inside and attract their food by waving the fronds surrounding their heads.

## 71. FORAMINIFERA.

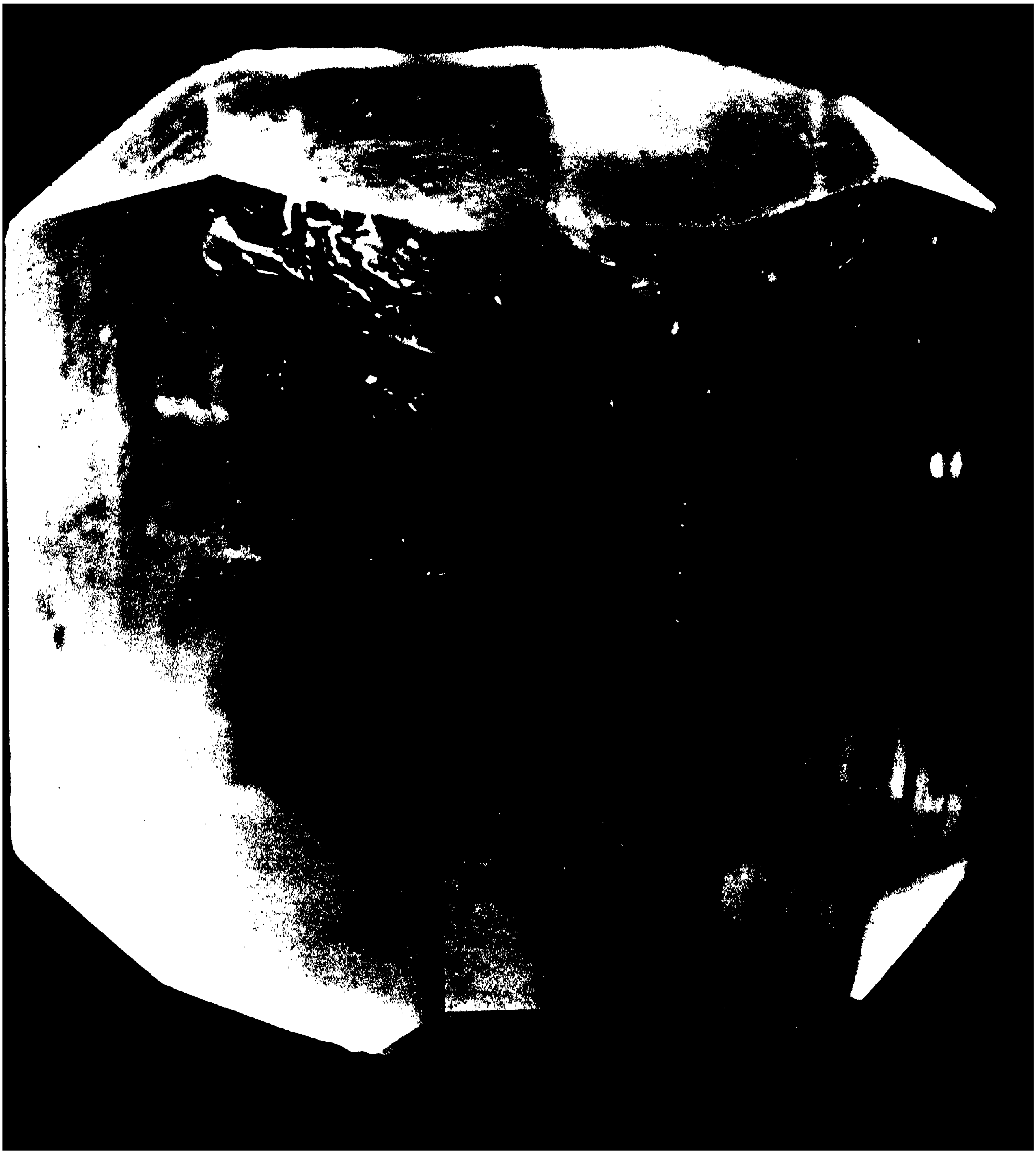
Foraminifera (the word really means "hole-bearers") are minute amœba-like creatures, which occupy shells made from lime extracted from the sea-water. In each shell are numerous small holes, through which protrude elongated wisps from the body, which are used as a means of swimming and of catching food.



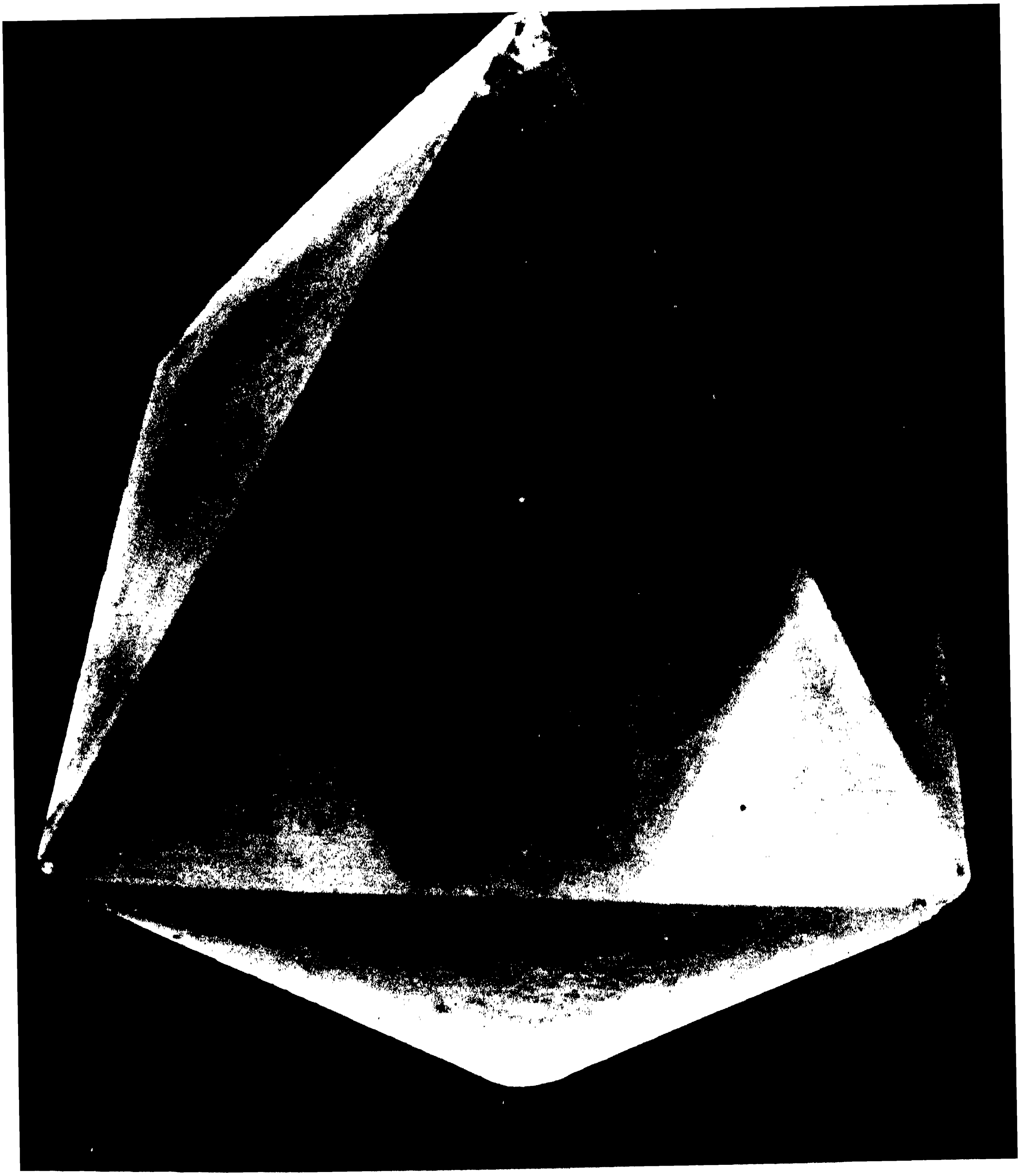


72. HEAD OF A GNAT—opposite.
The complete head is shown, with its compound eyes, tongue and antennæ. The long, tubular, and apparently transparent process should be noted, as this contains the lancets with which the gnat punctures the skin to inject poison or to suck nourishment.

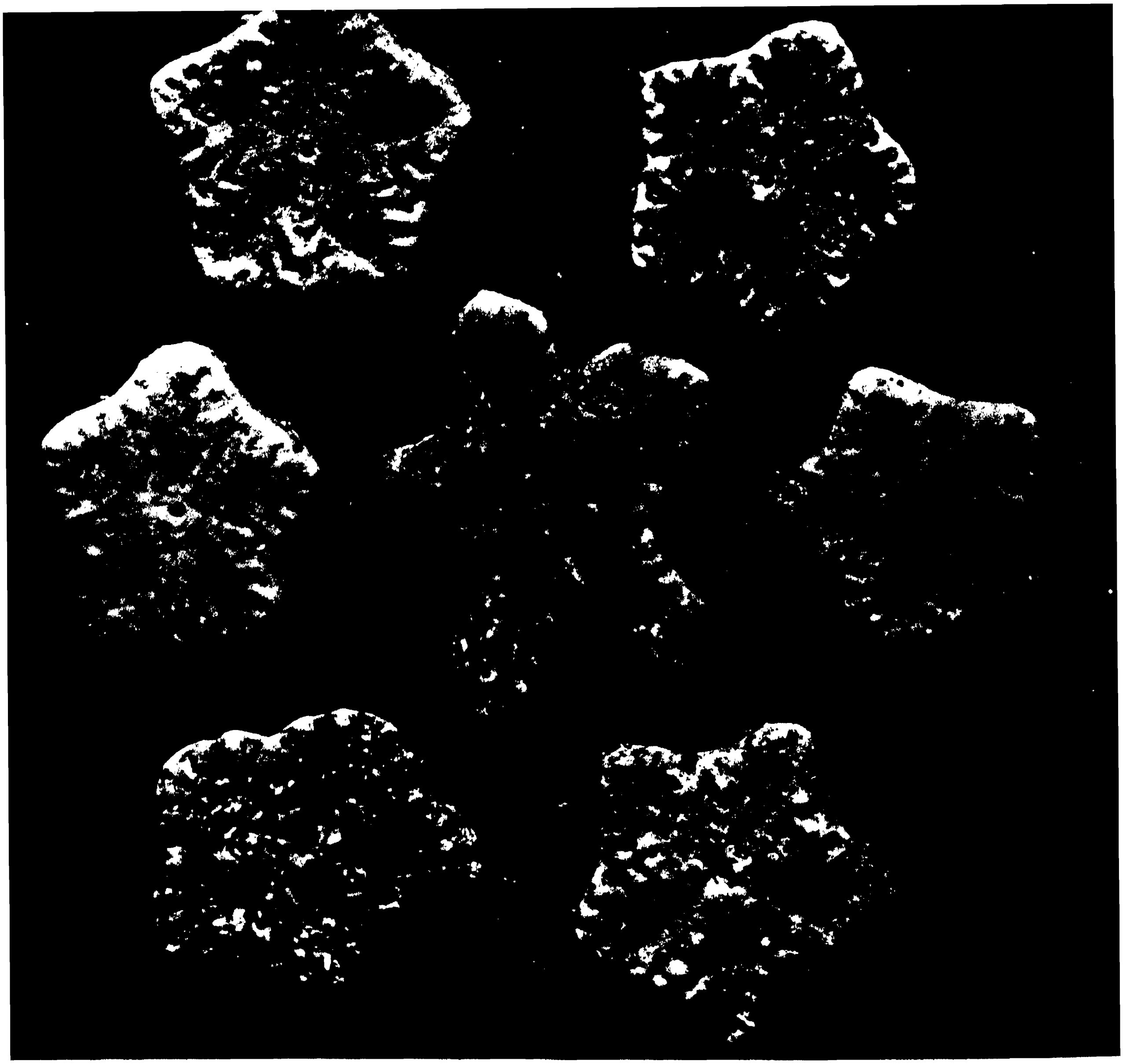
73. POLYSTOMELLA (Foraminifera).
The formation of the Foraminifera may be deduced from the exterior appéarance of the shells. In this illustration the shell has been dissolved away by means of acid, leaving only the delicate protoplasmic or jelly body of the animal.



74. MAGNESIUM AMMONIUM SULPHATE. A common chemical crystal. Provided that temperature is constant this chemical compound always forms a crystal of the same form. Note the exact proportions of the faces and regularity of angles.

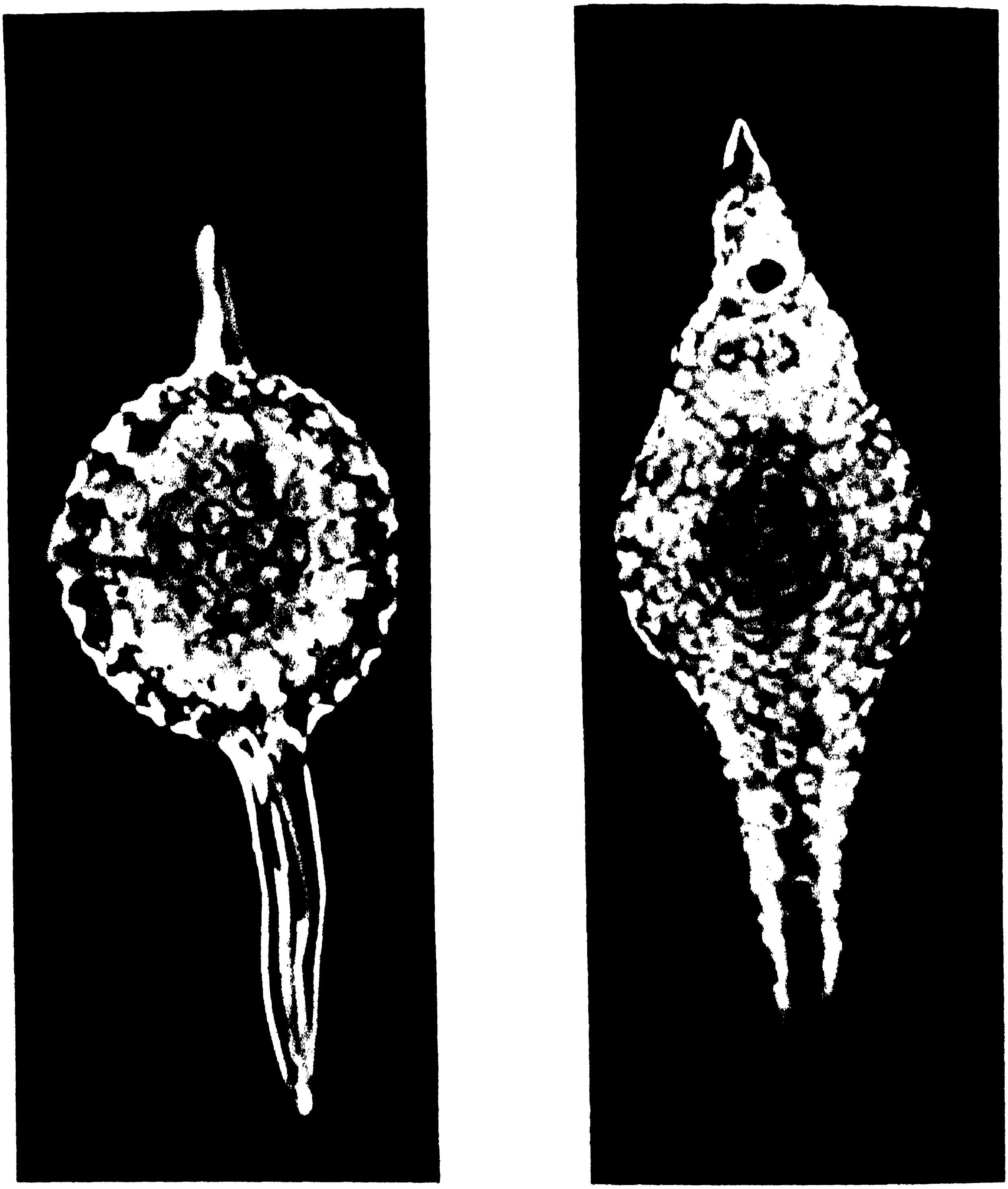


75. POTASSIUM ALUM.
Another example of a chemical crystal. Each chemical compound or element forms its own typical crystal, a feature that is of fundamental importance in many branches of scientific work.



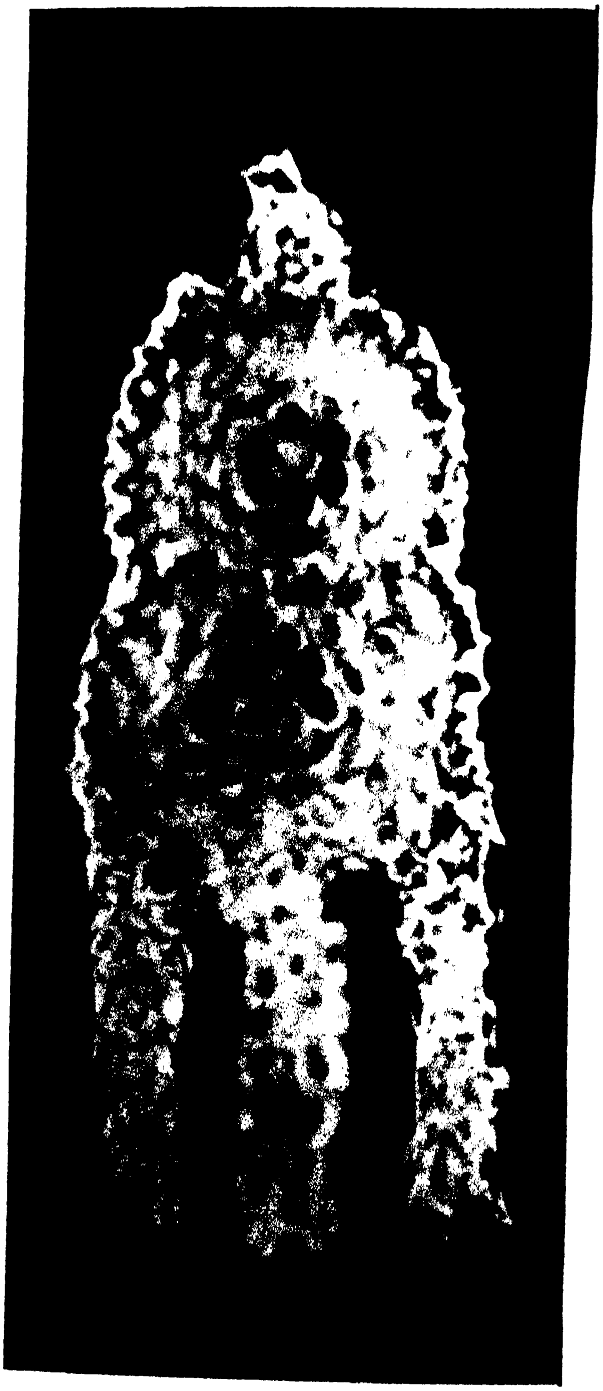
76. STARFISH.
These cases are made of carbonate of lime, and are very beautiful examples of the power of minute creatures in extracting salts from the surrounding water to make homes for themselves.

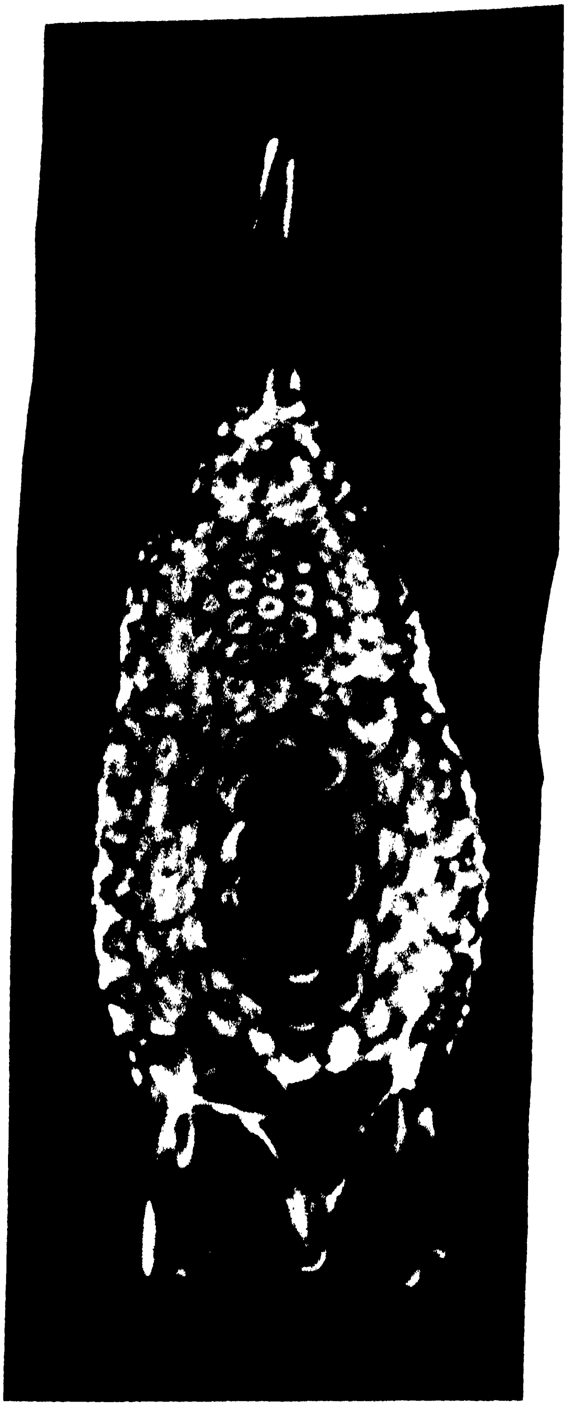
77. FORAMINIFERA—opposite.
The individuals forming this group are of greater size relatively than the diatoms previously described, but like them are minute free-swimming lumps of protoplasm and jelly.
Each member of the group, according to its type, selects microscopic grains of sand, mica or garnet and cements them into a shell or " test." The group of shells chosen for this illustration is from Ireland. The many beautiful patterns show clearly the rib-like reinforcement and indications of further structure which would be revealed under higher magnification.



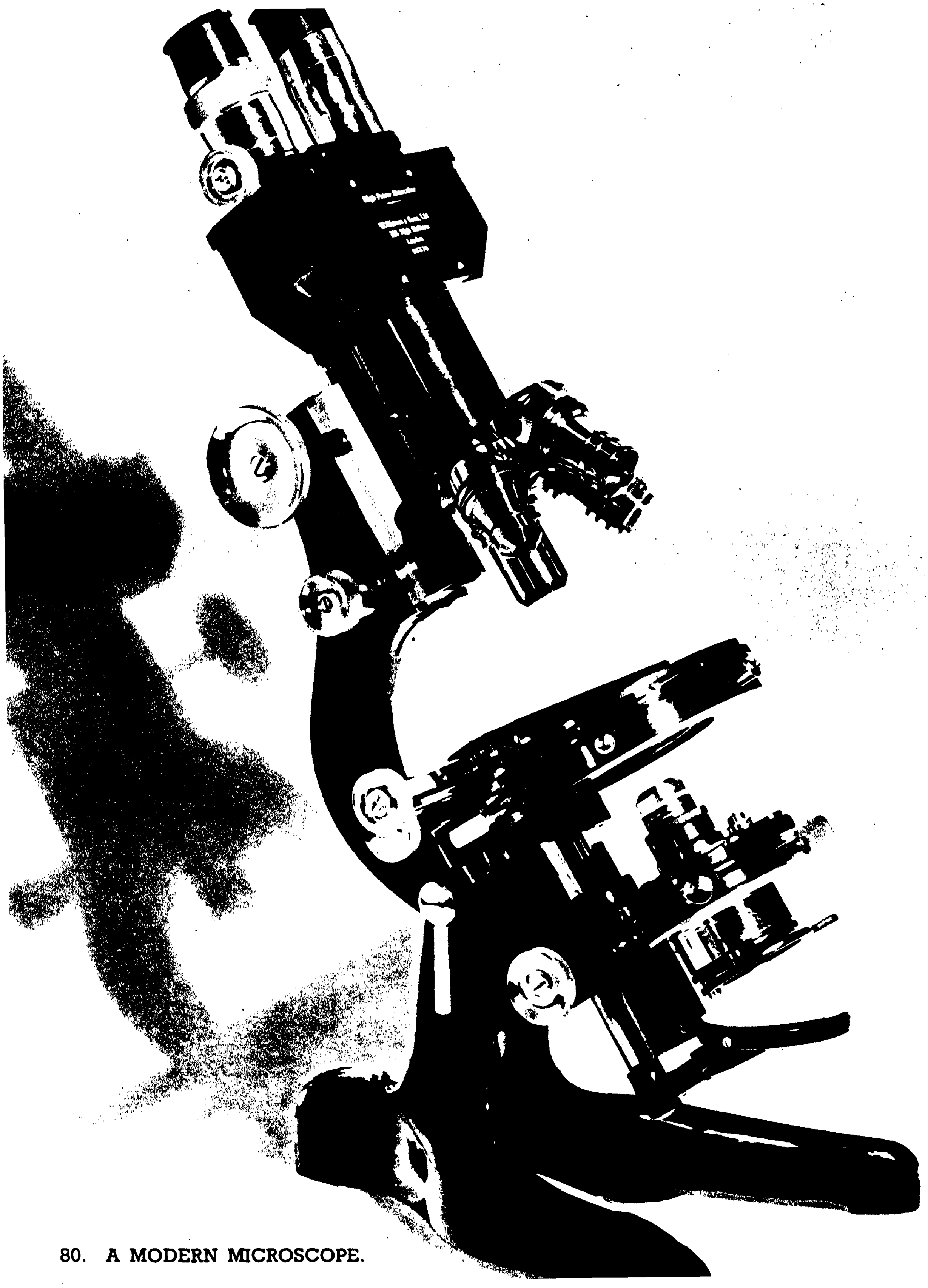
78 and 79. RADIOLARIA.

Further examples of the beauty of the infinitely small. As with the diatom family there are many species and each different member of the





family builds its own distinct pattern of shell. In examining these examples and admiring their delicate beauty the reader should remember the great pressure stress to which this and similar shells are subjected.



80. A MODERN MICROSCOPE.